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SOVIET SOIL SCIENCE

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PROBLEMS OF AGRICULTURAL CHEMISTRY IN THE USSR

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The development of agricultural chemistry has been inseparably linked with the economic activity of man. Progress in this science has led to the establishment of integral branches of chemical and mining industries, and to the organization of agriculture on a scientific basis in many districts where the productivity of land is now determined by the degree of use of mineral fertilizers and other chemical means of production.

Not long ago farmyard manure was regarded as the basic fertilizer. Today mineral fertilizers are a much more important source of nitrogen and phosphorus for plants. The first task of agricultural chemistry in the USSR is to determine where, when, how and to what extent nutrients can be supplied to plants by means of fertilizers. Second, but no less important — it is the best method of utilizing the natural nutrient reserves in USSR soils. The answers to these problems should be sought simultaneously and along parallel lines.

Agricultural production can be increased in two main ways: 1) by increasing the productivity of cultivated areas of arable land, meadow and pasture, and 2) by increasing the area of cultivated land, i. e. by reclaiming virgin and abandoned soils.

If a country possesses fertile soils that can be utilized without capital investment, the utilization of such soils will make possible rapid and economical increase in agricultural production. However, newly reclaimed land is low fertility and requires large expenditure on soil improvement and on organization of transport and mining, it is more profitable to spend capital on increasing productivity of land that has already been reclaimed.

In small countries such as Belgium, Holland and Germany the only practical way to increase productivity is by means of mineral fertilizers. We know that Holland increases its area of dry land by reclaiming land from the sea, but this adds very little to the area under cultivation,

whereas the application of large amounts of fertilizer per hectare of arable land has increased the agricultural production of that country many times.

In countries such as USSR, USA, Canada, the countries of South America and China, both methods of increasing agricultural production are possible. In the USSR more than 36 million hectares of virgin and old abandoned land have been reclaimed recently in a short time. This is a great achievement, of which our country is justifiably proud, for nothing like it has been known in the history of world agriculture.

In the USA during the war and post-war years the increase in production of mineral fertilizers increased the yield of grain crops and corn by about 150%.

Each country solves the problem of organizing its agricultural production according to its natural and economic conditions. The agriculture of the USSR can be developed by reclaiming new virgin lands and by increasing mineral fertilizer production. The latter is essential for increasing productivity in long-inhabited agricultural areas, which can be done without large additional expenditure on transportation and on the organization of farming.

Among the main points of Nikita S. Khrushchev's speech on "Standard figures for the development of the national economy of the USSR during 1959-1965" we read that, now that the great projects for reclaiming virgin and abandoned land, providing agriculture with techniques and increasing fertilizer production have been carried out, "the most important national economic task is to increase the yields of all agricultural crops."

The rapid development of the mineral fertilizer industry is caused by the fertilizer requirements of old agricultural regions with their arable soils, and also by the need to utilize fertile soils and newly reclaimed virgin land more fully.

The standard figures for the development of the national economy of the USSR over the next seven years envisage accelerating development of the chemical industry. Its production will be almost trebled; 140 large-scale chemical enterprises will be either completed or under construction.

Mineral fertilizers for agriculture will reach 31 million metric tons in 1965, i. e. three times more than in 1958 (10.3 million metric tons). There will also be a considerable qualitative improvement in the manufacture of mineral fertilizers, mainly through widening the assortment and increasing the production of concentrated fertilizers.

Accelerating development of the chemical industry will greatly increase production of insecticides, and fungicides; in particular manufacture of the extremely effective organo-phosphorus preparations will be developed. The manufacture of chemical means of weed control — herbicides — the wide application of which brings about profound changes in agricultural techniques for almost all crops, especially the extremely labor-consuming root crops, will be organized.

This development of branches of the chemical industry serving agriculture is indispensable for completing our most important national economic task — increasing the yields of all agricultural crops.

High and stable yields will be reached by wide use of the data of agricultural science and of recent experimental results. Scientific agricultural systems will be introduced according to the conditions of economic zones and of individual farms. Thus great possibilities are arising for utilization of all the new methods of improving yields and quality, and for capitalizing the advances of agricultural chemistry and of all the sciences studying production conditions in various zones, i. e. soil science, climatology, geobotany, etc.

There are two main methods of using mineral fertilizers: 1) 'intensive' (high rates of application) and 2) 'extensive' (low rates). With the intensive method, the main plant nutrients are given by means of fertilizers. With the extensive method fertilizers are applied only as supplementary plant nutrients during critical periods. For instance, even at a relatively high level of available phosphates in the soil, young plants without fully developed root systems respond positively to the combined application of phosphates with seed. This is the basis for combined application of granular superphosphate with seed for grain crops. Similarly fall grains may be given early-spring supplementary nutrition in the form of nitrogenous fertilizer when there is insufficient nitrate accumulation in the soil. Such extensive methods of fertilizer

use give a high return by producing additional grain per unit of fertilizer. For instance, one centner of granular superphosphate combined with seed gives a 3-4 centner increase of grain yield.

In the USSR the intensive fertilizer use is imposed more in districts producing cotton, sugar beet and other industrial crops that are supplied with nitrogen, phosphorus and potassium chiefly by means of mineral fertilizers given in large enough quantities to ensure high yields. The wide extensive use of fertilizer for grain crops has not yet been imposed in the USSR; but particular attention should be afforded to it. Fall grains should receive phosphorus at sowing time and nitrogen as a supplementary nutrient; spring grains should receive phosphorus at sowing time, and nitrogen in most districts. When virgin lands are being reclaimed a stock of fertilizers should follow the fleet of tractors.

The need for the application of very large amounts of mineral fertilizers in the USSR has been scientifically proved, but the application process requires further continuous agronomic work and the service of agricultural chemistry. The work of the agricultural chemist in production requires an immediate answer from scientific institutions to the question — which method will best serve agriculture in the various districts of the USSR.

Then there is the serious problem of large scale mapping and evaluation of soils. There are two methods of large-scale soil mapping. The first, adopted abroad, is an agricultural study of soils by means of large-scale determination of P, K and pH in soil samples collected from every two to four hectares of arable land. This method, which has been tested in practice, makes possible the economical and effective use of fertilizers. The second method, adopted in the USSR, is to examine the fields of sovkhozes and kolkhozes in order to establish the varieties of soils occurring in them. By this method large areas (100-1000 ha) are sometimes characterized by analyzing a few soil samples. It is useful for introducing rotations and organizing farms, and particularly for the reclamation of new land. It can be employed also for purposes of extensive fertilizer use. In many districts of the USSR however, fertilizers are already used intensively or, more frequently, fertilizer systems are employed that are transitional between extensive and intensive. Large-scale soil mapping, in which a single soil analysis is made for several hundred, or even thousand hectares, is of little value for practical fertil-

zer use, and so should be accompanied by detailed chemical study of soils and their characteristics based on large-scale analysis of sovkhoses and kolkhozes soils in all districts where fertilizers are important. A system of large-scale soil mapping must be evolved in order to take advantage of all the valuable features of the foreign system and of our own.

We should mention the evaluation of soil by soil quality or index, which has been given insufficient attention. During recent years a number of institutions have developed a method for soil quality. The principles followed abroad cannot be automatically applied to our conditions; we have to employ a method based on study and analysis of soils, in which the agricultural chemical characterization of soils plays an essential part.

There is another practical but extremely important problem raised by the support given to agriculture by agricultural chemistry. Agriculture already receives large amounts of fertilizers, but the economy suffers every year, through confusion in the matter of their use (losses during transportation and storage, and through incorrect application); losses are equal to the production capacity of several big factories. This can no longer be tolerated. Full utilization of all mineral fertilizers produced must be organized.

The application of chemistry to agriculture involves not only the general but also the intelligent use of chemical methods in agriculture; this means that the whole process of agricultural production must be checked by chemical methods, with special emphasis on the correct use of mineral fertilizers.

The soils of every farm field vary in the amount of nutrients they contain and in other chemical properties, so that only a large-scale analysis of soils from the production viewpoint can ensure correct fertilizer use. This point was clearly made (Pravda, December 18, 1958) by F. A. Karpov, Director of 'Bolshevik' the leading sovkhos in Serpukhov rayon, Moscow Oblast', at the December plenum of the Central Committee of the Communist Party. It should be mentioned that the production economy on this sovkhos was referred to by N. S. Khrushchev in his speech at the December plenum of the Central Committee of the Communist Party (see Pravda, December 16, 1958). The Dokuchayev Soil Institute of the Academy of Sciences, USSR, studied the chemistry of soils of this sovkhos from an agricultural viewpoint over a number of years. It was found that although its bottom land soils do not need liming, they were limed; although phosphates have little effect, they were applied at high rates; and although the soils' potash requirements were high, insufficient potash was given. The Institute's studies resulted in a reduction of expenditure on fertil-

izers and a more effective use of them. Thus we see that even on a well managed sovkhos fertilizers cannot be used correctly without chemical analysis of the soils.

The experience of East Germany and Poland indicates that we should establish laboratories (for large-scale agricultural chemical analysis) capable of analyzing 500-1000 soil samples per day. These laboratories should use tested, standard methods. The development of these methods is an important and responsible task for scientific institutes.

During 1959-1965 USSR agriculture will develop through the introduction of scientific systems of agriculture, adapted to the natural and economic conditions of each district and each farm.

A glance at the soil and climate maps of the USSR shows the wide variety of natural conditions in our Union. Agricultural techniques, rotations, plant varieties and species, fertilizer systems, methods of soil melioration — all must be adapted to local conditions.

The establishment of first-rate, independent centers for agricultural science in all republics and regions of the USSR will ensure the proper use of fertilizers, a yield increase and the introduction of scientific agricultural methods. Local agricultural chemical investigations are necessary for fertilizer use and correct farm management. Problems of fertilizer use in rotations and of the utilization of green manures, farmyard manure and other local fertilizers must be studied locally.

The application of chemistry to agriculture results in profound changes in the whole technique of farming. Growth of the most valuable crops often depends on the amount of fertilizers, on soil liming and on the use of insecticides, fungicides and herbicides. Adequate nitrogen in soil depends on bare fallow land. Our shortage of herbicides has caused the retention of the labor-consuming technique of sowing and cultivation of root crops. In the fields of the Dolgoprudnaya Agrochemical Experiment Station corn is growing this year on absolutely clean plots not cultivated after sowing, the soil having been sprayed with a special herbicide.

Plant varieties should be bred to suit given fertilizer systems. The increase in fertilizer manufacture creates an important problem in the selection of grain crops — the breeding of lodging-resistant varieties. The adaptation of crops to prevailing northern conditions depends on knowledge of plant growth regulation and development by changing their nutritional regime.

Clover for seed and for hay need different fertilizers, as do corn for grain and for feed, table and industrial potatoes, feeding and malting barley. The use of chemical methods

is specific to various branches of agriculture, hence the need for qualified agricultural chemists in all branches of agricultural experimentation. Without the establishment of agrochemical laboratories in experiment stations and in zonal institutes, local agricultural science cannot meet present-day production demands and scientific standards.

The first question answered by research workers in agricultural chemistry was: which nutrients are necessary for plant life, in what quantities and in what form. The application of chemistry to agriculture awaited a scientific answer to this question. Today our knowledge of plant nutrition is such that, with plants grown for practical purposes under glasshouse conditions, we sometimes prefer to dispense with soil and humus and to grow the plants in containers with water or sand, adding nutrient mixtures prescribed on the basis of agricultural chemistry. To regulate the rate of plant growth and development, special chemical means are used, such as growth-promoting substances and hormones. This does not, of course, imply that more research is unnecessary in this branch of science. Herbicides, micro-elements and radio-isotopes were only recently introduced into agricultural practice.

In biology, too, progress has resulted from the introduction of physical and chemical methods in recent years. In N. S. Khrushchev's speech at the 21st Meeting of the Communist Party he says: "The importance of the biological sciences will show a particular increase through the utilization in biology of advances in physics and chemistry. At the same time biochemistry, agricultural chemistry, biophysics, microbiology, virology, selection and genetics will be important." This observation is of cardinal importance for development of biological sciences in the USSR.

The application of modern physical and chemical methods to the biological sciences is new as is the existence of viruses and hormones. Present day experimental methods make possible the detailed study of essential processes in the life of plants.

The use of isotopes was, of course, a method which brought about fundamental changes in the experimental study of biological phenomena. Labelled atoms made it possible to study previously remote problems.

New methods in agricultural chemistry brought greater success to the study of plant root uptake of cations and anions from the soil and the determination of nutrient content in the soil. Until recently the possibility of determining the amounts of available nutrients in the soil was in doubt; now it is only a question of which method is the best. The isotope method provided means of determining the amounts of

available phosphates in the soil, and changed our ideas on the retrogradation of phosphorus fertilizers in the soil, and on the coefficient of their utilization and methods of applying them. The same will soon be done for nitrogen, potassium and microelements.

Modern methods make it possible to study in detail the laws governing plant nutrition under given soil conditions. We can now investigate experimentally the effect of the moisture, temperature and aeration of the soil, and of the composition reaction and osmotic pressure of soil solution on plant nutrition, and the part played in plant nutrition by various solid and liquid substances in the soil. All these investigations are necessary for finding the optimum methods and time of fertilizer application in both moist and arid regions and in both warm and cold climates.

It is now possible, using isotopes, to check each detail of fertilizer application techniques, the quality of work done by fertilizer distributing machines, and the results of outer-root nutrition. We can now study more effectively problems related to the accumulation and decomposition of humus in the soil, the use of green manures, and the movement and fixation of various soil elements. The problems of the biological fixation of nitrogen, of nitrogen metabolism in plants, and of protein and amino-acid synthesis can be thoroughly reconsidered.

Great possibilities are arising for studying the improvement of the quality of production by influencing plant metabolism.

One hundred years ago, in 1859, Charles Darwin's famous book *The Origin of species* was published. In it Darwin wrote of the "struggle for existence," by which he meant the dependence of one living creature on another, the struggle of individuals within the species, the struggle between representatives of different species and the struggle of living creatures with external physical conditions.

The interrelationships between living creatures and, in particular, between plants, have been studied little by agronomists, in spite of the fact that many agricultural problems, such as establishing the rate of sowing, determining optimal nutritional areas, and selecting mixed and pure stands are fundamentally connected with these interrelationships. It was no accident that Darwin, towards the end of his life, became interested in the Rothamsted experiments on fertilizing meadows, in which displacement of one species by another was observed.

By changing the nutritional conditions of adjacent plants we produce in them specific characteristics which give them an advantage in the struggle for existence. We examined

a number of publications the question of interrelationships between plants when fertilizers are applied to the soil.¹ The appearance of the method of labelled atoms opens up new possibilities for the study of this question. We can now study in detail where plants take up various nutrients from their own area of nutrition or from adjacent areas; how the exchange of substances takes place between plants and the soil and between neighboring plants (since plants not only absorb but also exude nutrients); and how plants utilize residual substances left by preceding crops. In short, we are able to study experimentally the fertilizing of the crop rather than of the plant (in most cases we fertilize the crop, the association of cultivated plants — not the individual plant).

The problem of increasing the photosynthetic activity of plants arises, since research workers are now very close to understanding the mechanism of photosynthesis.

The production of gibberellic acid has given a powerful fresh impetus to the use of growth-promoting substances. The hormone theory of plants, which opens up possibilities of chemical action on the rate and development of plant growth, has been re-established by Soviet scientists in its rights. New products acting on soil structure have appeared that are effective although very expensive.

The investigations of agricultural chemists and experimental agronomists have determined an agronomically desirable assortment of fertilizers, and agricultural requirements in various fertilizers have been computed. These, however, all relate to already existing types of fertilizer, which are by no means always ideal. For instance, from the standpoint of agricultural chemistry it is desirable that fertilizers should not contain unnecessary admixtures or undergo retrogradation in or be leached from the soil, and should possess good physical qualities, be readily available to plants, and should allow all methods of application — either before plowing, or by combine-drilling with seed or as outer-root nutrients. It is desirable that many fertilizers be mixed fertilizers containing nutrients in required proportions, etc.

The fulfillment, even partial, of these aims is a large and extremely complex task that can be accomplished only by the combined efforts of technologists and agricultural chemists working on specific materials.

D. N. Pryanishnikov wrote that "the task of agricultural chemistry is to study the cycle of substances in agriculture and to reveal methods

of acting on chemical processes occurring in the soil and in the plant which may increase yield or change its composition" (*Agrokimiya*, 1941).

Soviet agricultural chemists have been more occupied with the second element in this definition. There is not a single major agricultural crop for which effective methods of fertilizing and chemical means of controlling pests, diseases and weeds could not be proposed at this time. In recent years agricultural chemists have paid particular attention to methods of economical fertilizer application (use of granular superphosphate and fertilizer mixtures), outer-root nutrition with microelements (boron, molybdenum, zinc), various methods of mechanized fertilizer application for grain and root crops, the use of liquid nitrogenous fertilizers, etc. New practical measures for controlling salinization and solonchization of soils, for controlling the harmful action of soil acidity by applying magnesium fertilizers and molybdenum, new ways of utilizing green manures and fertilizing vegetable crops on floodplain soils, methods for the rapid determination of the fertilizer requirements of plants both by their analysis and from their external appearance, methods of using various new forms of fertilizers, herbicides, defoliant, etc., have been developed. We now have many progressive and effective agrochemical methods that will cause a sharp rise in agricultural yields and in output-per-man upon introduction.

Until recently the general questions of the cycle of substances in agriculture seemed to have little connection with immediate practical problems. This was quite understandable, since the amounts of fertilizers used in the USSR were so small that they did not play an important part in this cycle. However, rates of fertilizer application have been increasing gradually but steadily in a number of districts, and have begun, for some elements, to balance the removal of nutrients by crops, and later to exceed it. The study of the cycle of substances in these regions acquires practical importance.

But the importance of the cycle of substances was also shown in those old agricultural districts where there was no intensive use of fertilizers. In some districts the removal of nutrients by crops gradually led to the exhaustion of even the most fertile soils, for instance the potash depletion of the chernozems in the sugar-beet districts.

A fundamental natural law is that of the conservation of matter and energy. Agricultural chemists are now faced with the task of establishing quantitative indexes for the cycle of substances and energy in agriculture. The time is not far distant when agronomists will compile tables of the intake and utilization of substances and energy in agriculture similar to those now compiled in the chemical industry.

¹A. V. Sokolov. 1947. The distribution of nutrients in the soil and in crops. Izdatel'stvo Akademii Nauk SSSR.

J. Liebig, the founder of modern agricultural chemistry, was the first to raise the question of the conscious regulation of the exchange of substances between man and nature, and of the regulation of the cycle of substances in agriculture. But at that time there was not enough unbiased knowledge to permit more-or-less scientific calculations.

Today conditions are ripe for undertaking

work of this kind. The first socialist state in the world, which builds its national economy on a foundation of scientific data will undoubtedly also be the first to compile, on the basis of quantitative indexes, a plan for the regulation of the exchange of substances between man and nature and for the most effective utilization of soil resources and of the products of chemical industry.

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THE NATURE OF OXIDATION-REDUCTION PROCESSES IN SOLONETZES AND SOLODS

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The classical studies (7) on solonetz genesis firmly established the physicochemical nature of the phenomena producing the specific profile of these soils. All subsequent work on the solonetz process (1, 8 and others) has been based on the fact that the dispersive action of the Na^+ is the chief cause of variations in the stability of soil minerals and the organic part of the soil.

V. R. Vil'yams (5) drew attention to the part played by the biological factor in the formation of easily soluble sodium salts in the soil as a source of adsorbed sodium cation. This view was further developed by Kovda (9), Bazilevich (4), Antipov-Karatayev (2) and Frantsesson (12). Vil'yams and his successors took a different view from Gedroits on the formation in soil of sodium salts and adsorbed sodium; in dealing with the mechanism of formation of the characteristic solonetz profile they started from the physicochemical nature of this process.

Foreign soil scientists also accepted Gedroits's theory of solonetz-formation (17 and others). Thus the prevailing view of the genesis of solonchaks involves the recognition that the main cause of the differentiation of the solonchak profile into eluvial and illuvial horizons lies in the physicochemical processes of leaching, dispersion and the composition of water (hydrolysis) of soil colloids as a result of their saturation with the sodium cation.

Studies made by the Soil Science Faculty of the Timiryazev Agricultural Academy (13, 14) showed that iron compounds capable of migrating along the profile are formed by biological processes in soils of the forest-meadow zone. Observations made in the Saratov and Aktyubinsk oblasts (15) produced data showing that mobile iron compounds are formed during temporary excessive moistening in solonchaks and solods both of the chernozem and chestnut soil-climatic zones. In the genesis of solonchaks anaerobic biochemical processes developing during temporary excessive moistening are very important. The present paper gives

new data for the study of these processes in solonchaks and solods.

To ascertain the conditions for the development of biochemical processes we determined the moisture, temperature and reaction of soils, and also values of the oxidation-reduction potential. The intensity and trend of biochemical processes in solonchaks and solods during temporary excessive moistening were revealed by means of microbiological study and the determination of ferrous oxide. Saprophytic aerobic microorganisms were determined on hard plates (meat-peptone-agar), saprophytic anaerobic bacteria on MPA plates with 3% glucose. The various physiological groups of microorganisms were determined by the titration method on appropriate media.

Ya. N. Afanas'ev (3), I. I. Gantimurov (6) and I. P. Serdobol'skiy (11) showed by laboratory experiments the decisive effect of microorganisms in bringing about reducing conditions and the reduction of iron in various soils.

This was confirmed by work of the Soil Science Faculty of the Timiryazev Agricultural Academy (10, 15). The results of experiments show that the formation of ferrous compounds is either greatly inhibited or completely absent in the presence of antiseptics.

We studied, in laboratory experiments, the amount of sesquioxides extractable by water from temporarily excessive moistened solonchak soil in sterile and non-sterile media. Samples were taken from the upper horizons of a solonchak (400 g from horizon A and 1000 g from B_1) and passed through a 3 mm-opening sieve. The soils were placed in containers with tubes. To provide drainage, the lower part of each container was filled with broken glass and washed quartz sand. Then the sample from horizon B_1 was inserted, followed by soil from horizon A. The tube was closed by a rubber stopper with a glass tube inserted through it ending in a rubber tube with a clamp.

Container 1 was filled with boiled distilled water (natural anaerobic medium), and container 2 with a 5% formalin solution (sterile anaerobic medium).

After filling, container 2 was covered with a lid lubricated with vaseline and supplied with air through absorption apparatus containing Mohr salt and alkaline saturated pyrogallol solution. Every 3 weeks for 2 months the solutions in the containers were replaced with fresh solution. The sum of R_2O_3 , ferric oxide and ferrous oxide in the solutions was determined.

biosis ($rH_2 = 33-35$) in the upper horizons of both solod and solonetz under conditions of natural wetting. Under such conditions in summer these soils show only traces of mobile compounds of ferrous oxide. Ten days after excessive wetting 14-17 mg FeO/100 g of soil were found in the upper horizons.

These data show that the amount of reduced forms of iron was greater in solod than in solonetz. To explain the different amount of FeO in solonetz and solods, the nature of the microbiological processes in the soils studied must be

Table 1

R_2O_3 , Fe_2O_3 and FeO content of solutions (g/l)

No. of container	Solution in container	R_2O_3	Fe_2O_3	FeO
1	Distilled water	1.27	0.69	0.20 ^a
2	5% formalin solution		none	

^aDetermined only on the third occasion

Table 1 shows that when a solonetz soil is excessively wet and microbiological processes occur in it, a considerable amount of sesquioxides, especially iron, passes into the solution. When microbiological activity is suppressed sesquioxides do not pass into the solution. A series of similar experiments gave the same results.

Our results show that the loss of sesquioxides is connected to a considerable degree with their conversion into a mobile state not as a result of sodium dispersion but as a result of biochemical reducing processes developing in the soil. It should be borne in mind that under natural conditions of excessive moisture in solonetz and solods, reducing processes develop very rapidly and are observed as early as the second to third day.

In 1955-56 field observations were made to study the nature of biochemical processes occurring in solonetz soils and solods under temporary excessive moistening. In July 1955 an experiment was carried out on selected solonetz and solod areas (Kokchetav Oblast', Kazakhstan), involving artificial excessive wetting of these soils. Areas 1.5 x 2.0 m were walled in with soil and flooded with water, and the water level maintained at 10-15 cm for 10 days. Determinations were made on soils of selected areas before flooding and 10 days after it; the results are given in Tables 2 and 3.

Tables 2 and 3 show the prevalence of aro-

compared (Table 4). The total number of microorganisms in all horizons of solonetz was considerably smaller than in solod (both before and after artificial excessive wetting), which also explains the lower intensity of biochemical processes in solonetz.

Table 4 shows the nature of the microbiological processes occurring during excessive moisture. When solonetz and solods are excessively wet the number of microorganisms requiring aerobic conditions for their activity decreases sharply. The total number of aerobic microorganisms in the upper horizon of a solod (before flooding), for example, was 256,760 thousands and after flooding 28,340 thousands/1 g of soil. The number of anaerobic microorganisms increased 10 times (from 136 to 1551 thousands / g soil) during the experiment; that of nitrifying bacteria fell by 10 or 100 times after flooding (Table 4). A very sharp fall in numbers of aerobic cellulose-decomposing microorganisms was observed during excessive moisture (from 131 to 2.3 thousands / g soil in the A horizon of solod, and from 102 to 2.3 thousands in the A₂ horizon of solonetz).

The number of anaerobic cellulose-decomposing microorganisms in the upper horizons increased 100 times during the same period. The number of microorganisms was considerably higher in solod than in solonetz (Table 4). The number of aerobic microorganisms fell during wetting, but anaerobic microorganisms rose.

Table 2

Results of experiment with artificial excessive wetting of solonetz (Kokchetav Oblast¹)

Horizon	Depth, cm	Natural wetting		Excessive wetting	
		Moisture, %	FeOa, mg/100 g water	Moisture, %	FeOa, mg/100 g water
A ₂	0-2	2.4	none	126.6	14.7
B ₁	3-13	24.6	"	47.6	none
B ₂	25-35	24.3	"	32.7	"
C	70-80	20.9	"	25.4	"

^aExtraction with 0.1 N H₂SO₄ with soil:acid ratio 1:10

Table 3

Results of experiment with artificial excessive wetting of solod (Kokchetav Oblast¹)

Experimental treatment	Depth, cm	Moisture, %	rH ₂	FeO, mg/100 g soil
Natural wetting	0-4	15.5	35.4	Traces
	10-14	8.8	35.8	"
	40-45	26.6	33.4	"
	85-95	23.5	—	none
Excessive wetting	0-4	118.9	—	16.8
	10-14	21.5	32.5	7.0
	40-45	30.6	31.9	1.7
	85-95	31.4	37.2	Traces

This confirms again that one of the chief factors in the formation of ferrous oxide compounds, besides the presence of anaerobic microorganisms, is the presence of organic matter in the soil, especially water-soluble organic matter. More ferrous oxide compounds are formed in solods during excessive wetting than in solonchaks.

In 1956, we made similar observations on microflora and on conditions of the formation of ferrous oxide compounds under conditions of natural moisture (Saratov Oblast¹). On April 1, 1956 the moisture of soils in the Saratov Oblast¹ was relatively low (Table 5). Under these conditions the oxidation-reduction potential throughout all solonetz and solod horizons was fairly high (28-33 rH₂).

Microbiological activity fell considerably owing to an unfavorable temperature regime in the soils studied at the time of our observations.

Table 4

Numbers of microorganisms (thousands) in the experiment with artificial excessive wetting of soils of the Kokchetav Oblast¹

Soil	Genetic horizon	Depth, cm	Humus, %	Before wetting					After wetting								
				Total microorganisms (on MPA)		Nitrifying bacteria, by stages		Cellulose- decomposing bacteria	Total microorganisms (on MPA)		Nitrifying bacteria, by stages		Cellulose- decomposing bacteria				
				per 1 g of soil	per 1 mg of humus	I	II		per 1 g of soil	per 1 mg of humus	I	II					
								Aerobic					Anaer- obic	Aero-Anaer- bic obic	Aerobic	Anaer- obic	Aero-Anaer- bic obic
Solod, section 24	A ₁	0-5	28.8 ^a	256760	136	9005	0.5	1343	1100	431	4.3	1551	400	6	120	2.3	231
	A ₂	10-15	4.7	47152	98	1033	5.9	907	71	107	1.1	265	300	46	70	1.1	107
	B ₁	40-48	1.1	43560	20	1190	4.8	7	4	114	1.1	860	432	75	4	1.1	414
	B ₂	85-95	1.0	12960	2	1322	2.4	51	1	118	1.0	411	142	41	—	1.1	48
Solonetz, section 31	A ₂	0-2	6.3	2228	44	35	0.7	402	621	102	1.2	533	23	8	42	2.3	127
	B ₁	3-13	3.0	1144	29	38	0.9	112	27	114	1.2	271	4	9	4	1.4	21
	B ₂	25-35	4.3	4153	23	92	1.8	91	4	115	1.2	457	7	11	3	1.2	44
	C	70-80	0.7	841	not det.	117	not det.	not det.	not det.	115	1.0	not det.	6	—	not det.	1.2	—

^aOrganic matter

Table 5

Results of observations on solonetztes and solods of Saratov Oblast', 1956

Soil	Depth, cm	Temp. °C	Moisture, %	Oxidation-reduction potential, rH ₂	FeO ^a mg/100 g soil	Total microorganisms on MPA, thous. per 1 g soil	
						Aerobic	Anaerobic
Solonetz	0—9	17	27.8	28	0.25	669	4.3
	10—18	15	28.1	31	Traces	261	1.0
	18—32	13	27.3	31	none	180	3.1
	2—10	0	49.2	33	"	802	5.6
Solod	20—25	—1	29.2	31	"	316	1.0
	30—35	—1	18.5	32	"	198	1.0

^aExtraction with 3% AlCl₃ (soil: AlCl₃ = 1:2.5)

The total numbers of aerobic saprophytic microorganisms amounted to hundreds of thousands only; the numbers of anaerobic microorganisms in solonetztes and solods were very low (Table 5). This explains the low intensity of biochemical processes, causing an almost complete absence of ferrous oxide compounds in the soils.

In 1956 systematic observations were made of the dynamics of ferrous oxide and ferric oxide under natural conditions¹ in soils of 'kolks' [Translator's note: a Kolok is a small area of forest in a steppe] on the land of the Put' Lenina kolkhoz (Kokchetav Oblast', Kellerovskiy rayon). The depression was flooded with water for a long time after the snow thawing, so that observations could not begin until June 13. The results of our determinations are given in Tables 6 and 7. Point 1 was in the center of the 'kolok' (peaty, gleyed solod soil); point 2 was on the periphery of a depression (meadow-chnozem, slightly solodized).

and in the 15-20 cm layer 76.6%, 43.4 and 20.8 mg FeO/100 g soil were found.

The following trends in the dynamics of ferric and ferrous oxide are noted: the formation of the largest amounts of ferrous oxide corresponds to the lowest value for mobile forms of ferric oxide. As soil dries and oxidation processes increase, ferrous oxide disappears and at the same time the amount of mobile ferric oxide increases. In horizons A and B₁ the amount of mobile ferric oxide exceeds the amount of ferrous oxide being formed, which indicates the translocation of ferric oxide from the upper horizons.

These data confirm the statements of Yarkov (16) that ferrous oxide compounds formed during temporary anaerobiosis partly retain their mobility during subsequent oxidation and migrate through the soil profile with downward movement of water flow in the form of ferro-organic

Table 6

Field moisture at time of observation

Soil	Depth, cm	June 13	July 11	July 24	Aug. 10	Aug. 29
Peaty, gleyed solod (point 1)	0—5	117.4	21.8	26.2	38.5	26.3
	15—20	76.6	33.1	29.1	30.5	24.8
	35—40	31.1	27.8	28.1	26.6	24.9
Slightly solodized meadow-chnozem soil (point 2)	0—5	—	23.7	20.8	30.6	21.9
	15—20	—	20.6	18.5	18.0	18.4
	35—40	—	15.9	20.1	20.0	18.9

Tables 6 and 7 show that reducing processes leading to the formation of a considerable amount of ferrous oxide develop intensively in solods when excessively wet. Thus on June 13, when moisture in the 0-5 cm layer was 117.4%

compounds.

Excessively wet conditions are not clearly expressed on the periphery of the depression, so that large amounts of ferrous oxide are not formed here. However, the quantitative ratios in the dynamics of the ferric oxide and ferrous oxide forms reveal the same trend as in the soils at point 1.

¹Observations of L.I. Slutskaya and E.S. Yarkova.

OXIDATION-REDUCTION PROCESSES

Table 7

Dynamics of iron compounds (mg/100 g soil) (extraction with 0.1 N H₂SO₄)

Soil	Depth, cm	June 13		July 11		July 24		Aug. 10		Aug. 29	
		FeO	Fe ₂ O ₃	FeO	Fe ₂ O ₃	FeO	Fe ₂ O ₃	FeO	Fe ₂ O ₃	FeO	Fe ₂ O ₃
Peaty, gleyed solod (point 1)	0—5	43.4	3.8	3.4	11.3	1.3	2.8	none	17.0	0.8	14.7
	15—20	20.8	1.7	3.1	8.1	2.6	13.7	0.3	17.1	1.0	11.4
	35—40	—	—	2.9	8.4	6.4	7.2	0.3	13.8	1.2	12.6
Slightly solodized meadow- chernozem soil (point 2)	0—5	—	—	2.6	none	2.1	none	Tr.	1.1	0.7	1.9
	15—20	—	—	2.6	0.27	1.9	0.5	none	1.8	0.5	0.8
	35—40	—	—	2.9	none	1.3	1.4	"	3.0	0.7	1.9

Conclusions

1. Reducing processes arising during temporary excessive wetting are of considerable importance in the formation of solonchaks and solods.

2. Conditions arise in solonchaks and solods during excessive moisture in which the numbers of anaerobic saprophytic microorganisms, nitrites and aerobic cellulose-decomposing bacteria decrease; at the same time the numbers of anaerobic microorganisms increase.

3. Biological processes develop considerably more strongly in solod than in solonchak. Anaerobic microorganisms increase in numbers during wetting, whereas aerobic microorganisms decrease. This confirms once more the conditions for the formation of ferrous compounds are the presence in the soil of anaerobic microorganisms and humus, especially water-soluble humus.

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RIVER SUSPENSIONS AND SOILS¹

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In river hydrology, sediments are considered the products of erosion by water. Their formation in the river basin, their migration to other regions of the continent, and their deposition are duly investigated (4).

When considering river suspensions from the viewpoint of soil science, two aspects are determined by the place of river suspensions in the over-all pattern of transportation in nature. First, river suspensions are the products of soil and soil material erosion in the river basin; and second, they are the materials from which alluvia are formed and from which the alluvial soils subsequently developed.

Considering river suspensions within the general pattern of soil evolution and of the entire landscape, they are seen as a link in the life cycle of soil development which starts with formation in fresh alluvial deposits.

Recently, a series of papers on the sediments of USSR rivers has been published. A monograph by Lopatin deserves first mention; it includes a detailed review of the literature on this subject. Of equal note is Shamov's work which includes a map showing the extent of turbidity in USSR rivers (11), Shul'ts's monograph, and other studies.

From a review of publications on our country's river suspensions we conclude that extensive information is available on the solid charge (including information on quantities of sediments), while information on the composition of river suspensions is very limited. With few exceptions (mainly recent publications), this information is restricted to data on particle size analysis obtained by A. Sabanin's method. Omitting the consideration of this problem (4), we must state, however, that this one-sided char-

acterization of river suspensions constitutes an unfortunate gap which impedes the solution of many problems encountered in river hydrology (3). This gap considerably limits the possibilities of soil science in making additional characterizations of erosional processes in river basins and, more important, in making a more thorough genetic approach to the problem of soil formation in river valleys and deltas.

We shall attempt to illustrate this by using fairly limited factual data on the suspended materials of Rion River. We consider them from the viewpoint of their genetic relation to soils; soils of the river basin — suspensions of the rivers — soils of the river valley. Each of the two links will be reconsidered consecutively.

River Suspensions and Soil Erosion in the River Basin

In order to investigate suspensions of river water samples (100 liters) were taken daily from a depth of 0-20 cm, at a point 5 km from the estuary during a one-year period from September 1946 to 1947. The suspended material was collected, dried on water bath, and analyzed. The analytical results are given in Table 1.

Suspensions of Rion River contain a rather large quantity of organic matter (averaging slightly over 2%). The carbon:nitrogen ratio shows that the material is strongly humified, indicating its derivation from soil.² Our calculations show that in one year, Rion River discharges over 20,000 metric tons of organic matter to the sea. This amounts to 16.1 tons from one square kilometer, or 0.16 tons from

²Publications on river hydrology frequently indicate that river suspensions contain a high percentage (50% and over) of "organic matter." However, in accordance with the method used these figures constitute the loss from ignition. This terminological "misunderstanding" frequently misleads investigators in their calculations and correlations (12).

This work was conducted by the Georgian Academy of Science in connection with the improvement of the Khida bogs by silting. It was initiated by the V.V. Kuchayev Institute of Soil Science (V.A. Kovda).

Table 1

Characterization of suspended material of Rion River

Type of analysis	Result of analysis
Particle diameters:	
Fraction <0.01 mm, %	56.2 —84.4
Fraction <0.001 mm, %	21.1 —40.3
Aggregation coefficient	3.1 —11.5
Degree of aggregation:	
Diameter >0.05 mm, %	0.0 —63.8
Mineralogical composition:	
Diameter >0.01 mm of specific gravity 2.75-2.40 ^a	
Feldspars	38.6 —54.0
Minerals of the clay groups, %	18.5 —25.4
Micas, %	9.6 —14.6
Fragments of clay material, %	7.6 —13.4
Quartz, %	1.9 —9.4
Fragments of silica rocks, %	1.3 —1.7
Carbonates as CaCO ₃ , %	5.0 —11.4
Humus, %	1.48 —3.07
Total nitrogen, %	0.139—0.183
C:N	6.4 —9.6
Total phosphorus, %	0.175—0.210
Available P ₂ O ₅ , mg for 100 g sample (according to Dass)	1.13 —1.93
Nitrification capacity, mg/kg	12.6 —33.6
Ammonification capacity, mg/kg	33.1 —50.9

^aThe fraction of specific gravity of 2.75-2.40 constitutes over 85% of sample weight.

one hectare. It discharges more than 15,000 metric tons of nitrogen and more than 20,000 tons of phosphorus (7). Only an insignificant portion (a few percent) of products generated by erosion in the river basin finds its way to the large water current — to rivers (4, 10). These figures enlighten soil science and agriculture about the share of soil erosion products in a river basin which breaks away from the biological nitrogen cycle and nutritive ash elements on the continent and becomes an object of geochemical conversions in the ocean.

Table 1 also shows that the suspension composition of Rion River is not constant throughout the course of the year: the humus content in the suspension varies from 1.48%-3.07%; texture varies from fine clay loam to fine clay; the silt content varies within the limits of 21.1%-40.3%; and that of carbonates within the limits of 5.0%-11.4%. Of particular significance is the variation in the micro-aggregation of the suspension.

It is important to determine the causes of these variations and also the rules governing the suspension formation in order to characterize the erosion process in a river basin, and evaluate suspension as a soil forming material.

It is generally known that the solid discharge

of rivers is a function of: a) meteorological factors, b) elements of relief, c) geological soil factors, d) vegetation, and e) type of land utilization (10, 13). Each factor can be distinguished. Literature on river hydrology incorporates numerous factors which determine the solid discharge. However, insufficient study makes it difficult to establish a relationship between these factors and the solid discharge (10, 13).

We proceeded along a somewhat different course in our attempt to establish the rules governing the formation of solid river discharges. In studying this problem, we considered it expedient to combine the investigation of the dynamics of the process (variations in the composition of suspension as related to changes in physical, geographic and economic conditions in the river basin) with a qualitative characterization of river suspension.

Such factors of the solid discharge as the geological soil conditions and relief of the river basin should be considered constant in the course of a yearly cycle. Therefore, the dynamics of the suspension composition during the year are determined, in the first place, by the meteorological conditions, i.e. by weather conditions and annual seasonal changes, and also to a certain degree by vegetation as related to the

type of land utilization.

To establish the effect of weather conditions (regime of atmospheric precipitation) on the suspension composition of Rion River we compared the daily average atmospheric precipitation in the river basin with the composition of suspension.³ In the case of carbonates, the relationship is clearly shown in Table 2. Calculations indicate that suspensions contain the highest amount of carbonates during the period of lowest atmospheric precipitation in the river basin. During flood periods caused by heavy rain, the carbonate content in suspension declines to a minimum.

the carbonate content (products of calcareous Karst zone erosion) increases. An attempt to establish a relationship between atmospheric precipitation in the river basin and other data on the composition of suspensions (humus, particles and micro-aggregates) was unsuccessful. In this case, a different relationship, namely that between the composition of suspensions and the seasonal changes in the river basin, is clearly evident. (Table 3 and Fig. 1). According to Table 3, the annual cycle in relation to the composition of river suspensions can be divided into the following three hydrological periods: autumn-winter, spring, and summer; each period is characterized by a certain

Table 2

Carbonate content in the suspension of Rion River and the amount of atmospheric precipitation in the basin

Type of suspension	Number of samples	Carbonate content (in % of CaCO ₃)	Daily aver. of atmos. precip. in the Rion basin, mma ^a
Suspension with a maximum content of carbonates (average, 10.2%)	6	9.8—11.4	2.4
Suspension with the minimum content of carbonates (average, 6.1%)	5	5.0— 6.8	22.3

^aFor two days preceding the day of water sampling.

To explain the relationship between the carbonate content in river suspensions and atmospheric precipitation in the river basin, one must bear in mind that in its middle course the Rion River crosses a calcareous Karst zone, forming a longitudinal profile in the thick calcareous stratum. Also, the soils of the Rion basin, particularly in its elevated zone, are strongly leached with respect to carbonates. Therefore, the carbonate content in suspension decreases during the period of atmospheric precipitations in the river basin when the suspensions contain an increased amount of products generated by surface soil erosion.

On the other hand, during the rainless period at sites where the river forms the most energetic longitudinal profile by eroding the calcareous stratum, the suspensions contain an increased amount of products generated by the deep sited erosion of the river bed. During this period

combination of data on the composition of suspensions (humus, carbonates, clay fraction, micro-aggregates).

The explanation of changes in the suspension composition caused by hydrological periods was based on a differentiated approach to the river basin and related to the suspension supply zones (6). Annual changes in the composition of suspensions are determined by the uneven inflow of erosion products from different parts of the basin to the river system as caused by the seasonal changes in physiogeographic conditions. These changes in the composition of suspensions are also determined by the different composition of erosion products depending on the differences in the soils and parent materials of the basin (Table 3).

River Suspension and Soils of River Floodplains

Let us consider the second link — suspensions in river and the soils in river floodplains. In the same territory, we shall also follow the fate of the most essential elements of soil fertility (organic matter, aggregation, carbonates) in the following two stages of the evolution: deposition of suspensions and the process

³ The daily average of atmospheric precipitation was calculated from the daily precipitation of 25 meteorological stations located in the river basin. A consideration was made in further calculations: that 1 to 2 days are required for the flood water of the upper (elevated) zone to reach the lower zone of the river.

Table 3
Changes in the suspension composition of Rion River according to hydrological periods of the year

Season	Months (1946-1947)	Composition of suspension					Change in composition of suspension compared with preceding period	Characteristic of suspension supply zone of the river
		Humus	Carbonates as CaCO_3	Clay cont. (<0.001 mm diam)	Micro-aggre. (>0.5 mm)			
					in %	mm		
Autumn-winter	November	2.33	7.2	31.55	13.23	Increasing content of clay fraction and humus (to a maximum). Substantial increase in micro-aggregates (to a maximum). Decreasing content of carbonates (to a minimum).	Smallest area of the zone, limited to a territory where precipitation prevails during this season (horizontally, 1000 m above sea level). Zone with a large plowed area where the prevailing crops are those thoroughly plowed (corn) and plantations of subtropical crops and vineyards not covered by grass during this period time of the year. Non-calcareous soils prevail.	
	December	2.03	7.3	28.47	—			
Average for the period	January	2.36	7.9	35.52	30.74	Decrease of clay fraction (to a minimum). Decreasing content of humus and micro-aggregates. Increasing content of carbonates (to a maximum).	Zone area widens when compared to the autumn-winter period, owing to snow melt in the central mountain area (1000-2000 m above sea level), which is substantially a calcareous Karst area. A decrease in precipitation in the zone located below 1000 m minimizes the part of this zone in supplying the river with suspension.	
	February	2.35	7.9	34.00	22.75			
Spring	March	2.17	8.7	29.32	—	Increasing content of clay fraction. Decreasing content of humus and micro-aggregates (to a minimum). Decreasing amount of carbonates.	Largest area of the zone, covering the entire river basin except for the area of permanent snow cover. During this period, grass vegetation serves as the best protection against soil surface erosion.	
	April	1.93	9.0	25.33	—			
Average for the period	May	2.01	8.8	26.25	8.91	Increasing content of clay fraction. Decreasing content of humus and micro-aggregates (to a minimum). Decreasing amount of carbonates.		
		2.04	8.8	26.97	8.91			
Summer-autumn	June	2.14	7.2	32.80	8.35	Increasing content of clay fraction. Decreasing content of humus and micro-aggregates (to a minimum). Decreasing amount of carbonates.		
	July	1.89	8.0	32.98	8.24			
Average for the period	August	2.00	8.2	29.86	3.58	Increasing content of clay fraction. Decreasing content of humus and micro-aggregates (to a minimum). Decreasing amount of carbonates.		
	September	1.92	8.6	29.61	—			
Average for the year	October	1.83	8.6	29.24	4.05			
		1.96	8.1	30.90	6.06			
		2.08	8.1	31.16	12.48			

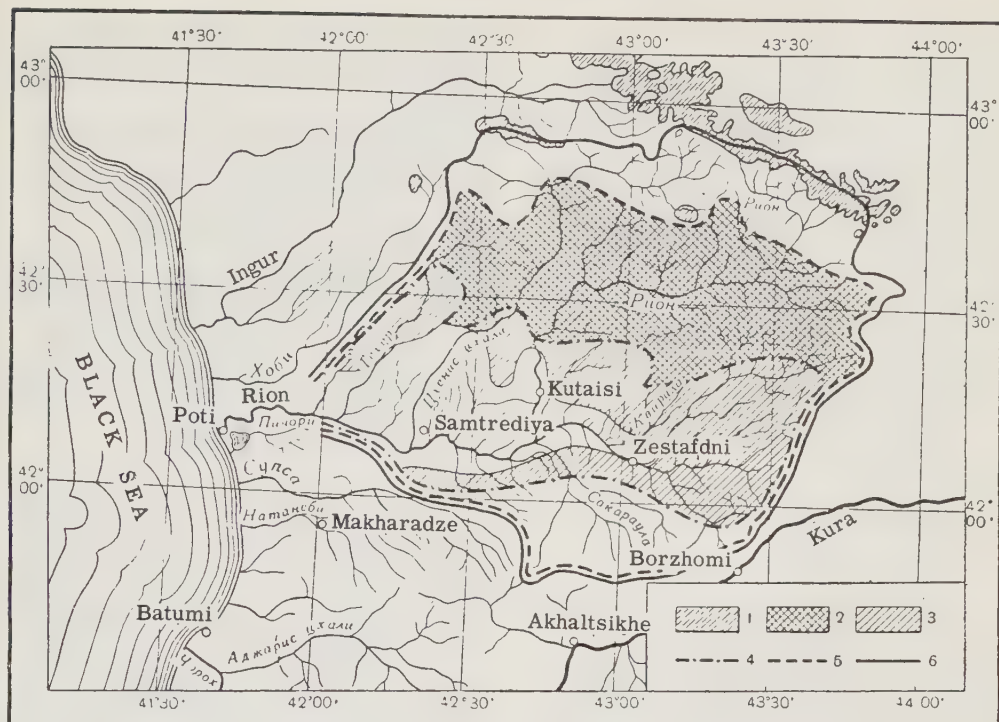


Fig. 1. - Zones of supplying suspension to Rion River and soil erosion according to hydrological periods.

1 - areas of contemporary glaciation. Zones of increasing soil erosion: 2 - spring; 3 - autumn-winter. Borders of supply zones: 4 - autumn-winter; 5 - spring; 6 - summer-autumn.

of soil formation. To a certain extent, we had an opportunity to follow these processes under "ideal" conditions, i.e. under those of a "large model" provided by the Kolkhida bog soil reclamation by the deposition of silt from the Rion River (8, 9). In time, the latter process was considerably separated from that of soil formation because of intensive depositions of suspensions. Thus, certain peculiar aspects of the link are revealed: suspensions from river — soils of the river floodplain. Under natural conditions, these aspects are obscured because the process of soil formation is superimposed on that of the alluvium.

Conditions of deposition of suspensions during the spring flood period and the evolution of soil formation in river floodplains were studied by Vil'yams (1). These processes proceed in a different manner in the floodplains of Rion River because of the essentially different physical-geographic conditions in the humid subtropical zone of Western Transcaucasia. Particularly, a differentiation of suspensions according to texture (micro-aggregate, to be more exact) takes place during their deposition.

Aggregation

The micro-aggregates of Rion River suspensions vary considerably (aggregation coefficient 3.1-11.5) and substantially in the hydrological periods; this can be explained by the conditions governing the formation discharges in the river basin. At the same time, calculations (and the previously mentioned concept of formation of solid discharges in the Rion River) indicate that the micro-aggregates of suspensions have a comparatively weak connection with their texture (correlation coefficient $r = \pm 0.59$). Figure 2 shows graphically that a classification of suspensions by texture yields only slight variations of the aggregation coefficient within the limits of 6.1-7.5.

A curve for soils developed on silting deposits has a substantially different appearance. In this case, a wide range of textures is combined with variations in the aggregation coefficient ranging from 3.7 (for sands) to 11.1 (for fine clay loam).

While the right portion of the curve satisfies the generally accepted concepts (increase in micro-aggregates with the fineness of texture), the left portion calls for some clarification.

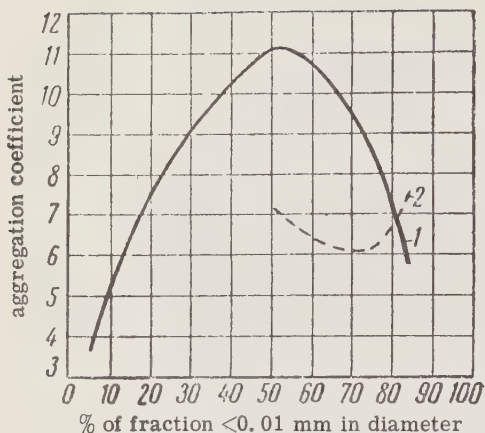


Fig. 2. - Dependence between the aggregation coefficient and the composition of silted soils and suspensions of Rion River.

1 - soils; 2 - suspensions in river.

tion. The micro-aggregate analysis of Rion River suspensions established their clay fraction content at 3.42%-9.17%. During the deposition of suspensions, this most dispersed fraction is carried out by the water stream and deposited in the lower part of the silting land where clay deposits are formed. The emerging process of gleying increases the dispersion of the deposit (9). These two circumstances determine the shape of the curve in the right ("clayey") portion of the diagram.

Thus, the differentiation of suspensions during deposition serves to correlate a good micro-aggregation of the main part of silting deposits (medium and fine-clay loams) with the formation of clay and highly dispersed materials, mainly on the periphery of the territory. Further changes in aggregation under the influences of meadow and bog processes were considered in our previously published studies (8, 9).

Organic Matter

We found that during the deposition of suspensions they are differentiated not only by texture but also by organic matter content. This is accompanied by a decrease in the humus content of coarser textured fractions and a humus enrichment of finer fractions. Thus, the relationship between the texture and humus contents in deposits obtained by silting the area for improvement purposes is clearly demonstrated (8). The humus profile of silted deposits is formed in this manner. Only later a curve of biological humus accumulation is superimposed on the humus profile of silted deposits as a result of soil formations in the silted territory. Consequently, six years after the end of silting the

area, we established that the distribution of humus along the profile of silted deposits was a result of the formation of deposits by silting.

Thus we conclude that the humus of silted soils is not of uniform origin; it comprises the humus of "alluvial" origin — humus of river suspensions (products of soil erosion in the river basin) and the humus of "soil" origin — the product of biological accumulation of organic matter in the upper horizon of silting deposits. Calculations show that a one-meter thick layer of silted soil contains 150-200 metric tons of humus per hectare; by approximate calculations, the prevailing humus, which constitutes 90%-95% of the total organic matter, is of "alluvial" origin while humus of "soil" origin constitutes only 5%-10%.

There is reason to believe that this quality in humus origin is characteristic not only in silted soils but also in those formed on natural alluvium. However, the latter contain a comparatively higher share of humus of "soil" origin as a result of the greater biological conversion of alluvium.

Since the composition of organic matter in soils reflects the nature of and, consequently, affects the process of soil formation, we must recognize that the influences of soils of the eroding part of the river basin on the floodplain soils are mainly evident through their organic matter. Specifically, the large variety, which is typical of the vertical zoning of Western Transcaucasia, should be evident in the soils of Kolkhida. A combined qualitative characteristic of the organic matter in soils of the river basin, alluvia and floodplains, would be of considerable use in establishing rules governing the formation of alluvia and in strengthening the approach to the origin of meadow (alluvial) soils.

Carbonates

A fairly even distribution of carbonates along the profile is characteristic for the principle mass of thick silting deposits to improve the land. It has an average carbonate content of the suspension of Rion River (8.1%). The previously mentioned highly gleyed clays, where the carbonate content is 2%-3% and lower, constitute an exception.

Considering the work of Wityns (14), we naturally assumed that the decreasing amount of carbonates in clay gleyed deposits should be attributed to their decomposition under the bog process. However, the fractional analysis of the suspension shows that their clay fraction contains nearly 3% of carbonates (Table 4). Therefore, the decreasing amount of carbonates in clay deposits may be considered as a result of differentiation by the micro-aggregate composition of suspensions in the course of their

Table 4

Composition of suspension of Rion^a River
(Sample No. 30)

Diameter of particles, mm	Content of the fraction	Hygroscopic water	Carbonates as CaCO ₃	Humus	Available P ₂ O ₅ according to Dass
< 0.001	9.28	5.65	2.9	2.10	1.76
0.001 — 0.01	49.01	3.35	8.3	2.18	1.62
0.01 — 0.05	35.56	2.58	8.6	2.29	1.32
> 0.05	6.15	1.88	8.3	1.88	1.40

^aFractions were separated by elutriation without preliminary physical and chemical pre-treatment.

position.

Laboratory experiments with artificial gleying of silted soils did not show the intensive carbonate decomposition which was also observed in Witvyns in Latvian soils.

The assembled material shows how important is to investigate the soils formed on alluvium to determine the composition of suspensions and the conditions of their deposition. Current economic developments, particularly the development of agriculture, calls for a broader approach to the investigation of river suspensions; a comprehensive investigation of their composition; and the establishment of rules which govern their formation, transportation and deposition. In soil conservation, the composition of river suspensions and their seasonal dynamics may serve as one of the diagnostic indicators of soil conditions in the river basin and the intensity of soil erosion. A full scientific and productive characterization of suspension and delta deposits, as well as of soils developed on alluvial and irrigational deposits, cannot be provided without a knowledge of the composition of suspensions (2, 5).

Therefore, the problems of soil science and the interests of agricultural production show the serious need for complete and detailed investigations in the study of river suspensions, and also for the establishment of rules which govern the regime and composition of suspensions. The development of such investigations opens a bright prospect for the knowledge of suspensions which is directly related to a series of biological and geologic subjects concerned with the conversion of matter in nature and in soil formation. The knowledge of suspensions will also correlate the methods of investigation with the physical aspects of

the process studied by concentrating on the needs of agriculture.

Conclusions

1. In this article we consider the river suspension as an element of geographical landscape, specifically, as a connecting link between the soils of the eroded part of a river basin and those of river valleys and deltas formed on alluvium.

2. Using the Rion River as an example, we demonstrated the need for a knowledge of the many sided qualitative characteristics of river suspensions in order to establish the rules governing their formation, particularly, for the characterization of soil erosion.

A differentiated approach to the river basin which would account for all factors determining the composition and dynamics of river suspensions is essential. The factors are: geology and geography; hydrological characteristics; climate; vegetation and; finally, the agricultural utilization of land in the river basin.

On the basis of the physiogeographic analysis, it is expedient to introduce a concept of alluvial supply zones in the river, and of changes in these zones in the various hydrological periods of the year. An alluvial supply zone must be evident in the basin of any large river. However, it is specifically evident in mountainous rivers, from the influences of vertical zoning.

3. The knowledge of river suspension composition and of conditions of deposition makes it possible to execute a thorough genetic analysis of the development of soil formations on alluvium. A detailed study of river suspensions is of particular significance for the Southern

zone of the USSR and for the South-East of the European part, where muddiness of rivers and the amount of deposited sediments is highest (4, 10).

4. The present methods of investigating river suspensions used in river hydrology must be modified and improved in accordance with the requirements of agriculture and the possibility of their utilization in soil science.

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IRRIGATION SEDIMENTS OF THE AMU-DAR'YA RIVER AS A FACTOR IN FERTILITY OF IRRIGATED SOILS¹

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The utilization of sediments from irrigation waters is a very important problem in irrigated farming. But our knowledge of their composition is insignificant, despite its importance. The few data available are concerned mainly with their particle sizes. The chemical and mineralogical composition of suspension in irrigation is almost unknown. The fertility of sediments from irrigation has also been given inadequate study. Thus the controversial question as to whether the suspensions should be added onto irrigated fields or flocculated in settling basins remains unresolved.

Since insufficient study has been given to suspensions in general, and to their chemical and mineralogical composition in particular, we made a special study in 1954-1956 of the suspensions of the Amu-Dar'ya River and various sections of the Kegeyli irrigation system, which draws water from this river. According to some authors, the bed load for the Amu-Dar'ya River amounts to 8%-10% of the suspension. It consists mainly of sand particles. Hence it contains only an insignificant amount of fertile components and affects mainly the physical properties of the soils, making their texture coarser. The bed load and earthy fertilizers reach the fields when the canals are cleaned. The irrigating water, as a rule, does not carry the bed load onto the fields. Therefore, we did not study the bed load.

Data on the amount of suspension in the water of Amu-Dar'ya River and various parts of the irrigation system are given in Table 1. On the average, water of Amu-Dar'ya River contains 4.5 g/l of suspended material. This rate rises considerably during the growing season. Maximum turbidity was observed

during the flood that ordinarily begins in the middle of May. During the growing season, the water turbidity of Kegeyli irrigation system averages 3.7 g/l.

In the particle-size analysis of the suspensions (Table 2) particle diameters <0.01 mm are prevalent. The proportion of coarse sands in the suspension is insignificant, amounting only to tenths or hundredths of a percent. If we classify the suspensions according to soil particle size (N. A. Kachinskiy), those studied can be classed as fine clay loams and coarse clays.

As the water moves from the head to the periphery of the irrigation system, the quantity of suspension decreases and the particle diameters become finer, because the coarse fractions settle out and the particles are gradually broken up enroute. The total of particles <0.01 mm in diameter at the beginning of the irrigation network amounts to a little more than 50% and at the end of the system it reaches 80% or more. But these general principles sometimes do not hold true because of local scouring of the streambed in some sectors of a canal or the influx of discard waters.

Turbid irrigation water enriches the soil with fine particles and makes its texture finer. This has been noted repeatedly earlier (4, 6, and others). As a result the physical properties of soils toward the far end of oases are sometimes adversely affected. But practical means have been developed to control these bad effects (mixing in sand, adding coarse sediments from the canals to the fields, etc.). Analysis of data in the literature on the fertilizer value of the sediments (3, 4, 5, 11, 12, and others) led us to conclude that, before the sediments are added to the fields, their properties should be investigated together with the properties of the soils that are to receive them.

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The chemistry and mineralogy of the suspen-

Table 1

Content of suspension in the water of Amu-Dar'ya River and in various sections of the irrigation system, g/l

Sampling location	May 26-31, 1954 (average level)	May 1-7, 1955 (after spring flood)	May 12-13, 1955	June 20-29, 1955
	Flood stage			
Amu-Dar'ya River, Kyzkytken settlement	—	1.56	5.61	5.03
Kyzkytken canal, head	3.90	1.60	6.42	4.29
Kyzkytken canal, town of Nukus	3.30			2.68
Kegeyli canal, head	3.60	1.24	4.80	3.31
Kegeyli canal 7 m from town of Khalbada	3.90	1.64	4.84	3.95
Kegeyli canal, town of Chimbaya	3.90	1.36	5.00	4.71
Ava-Dzhab canal		3.70		4.55
Manzhul'-Dzhab reservoir	2.60	1.58		0.73

sions were studied when the water level was at average height (samples were taken from May 26-31, 1954). Table 3 shows that the total chemical analysis of the suspensions is fairly uniform. But the suspensions of Amu-Dar'ya River and the Manzhul'-Dzhab reservoir are relatively low in silica and rich in sesquioxides of calcium and magnesium, as compared to the suspensions of the Kyzkytken trunk canal. The deviations observed are due to differences in particle sizes of the suspensions. Clay particles (<0.001 mm in diameter) make up 30.1% of the suspensions of Amu-Dar'ya River, 30.85% of the suspensions of Manzhul'-Dzhab reservoir, and only 21.85% of the suspensions of Kyzkytken canal.

The other components of the suspensions of different parts of the Kegeyli irrigation system do not vary much in concentration. The suspensions contain considerable total amounts of calcium, potassium, phosphorus, manganese, and titanium. The silica-sesquioxide ratio varies from 4.76%-5.55%.

Comparison of the suspensions with loesses (Table 4) shows a big difference. Loesses con-

tain more silica, calcium, and sodium than the suspensions in the river. The suspended material contains more of the primary, less weathered minerals and rock fragments carried down from the hills by temporary streams. A high content of sesquioxides of magnesium and calcium is characteristic of the suspensions of the Amu-Dar'ya River.

The exchange capacity of the suspended materials was determined by B. P. Nikol'skiy's method, as modified by P. G. Grabarova and Z. A. Uvarova (application of barium chloride buffer solution to the determination of the exchange capacity of carbonate soils). The exchangeable potassium and sodium were displaced from the soil by a method proposed by K. K. Gedroits. Sodium was determined by zinc uranyl, and potassium by spectral analysis. Determination of exchangeable calcium and magnesium in highly carbonated and gypsum-containing soils is difficult, since there are no reliable methods for their determination. Therefore, the total exchangeable calcium and magnesium was determined by difference.

Analysis of the data presented in Table 5 shows that the adsorption capacity of the suspension is low (8.3-11.1 meq/100 g), and the adsorption complex is saturated chiefly with calcium (66%-80% of the exchange capacity). The proportion of exchangeable potassium among the exchangeable cations is high (13.2%-22.4% of the exchange capacity); sodium is always present (6.8%-13.2% of the exchange capacity).

It is possible that the increased content of exchangeable potassium and sodium in the soils of Amu-Dar'ya River valley is responsible for their tendency toward takyrs formation.

It should be noted that the suspended materials are not rich in nitrogen (0.053%) and humus (0.72% of a 100 g sample).

Mineralogical analysis of the suspended materials (0.01-0.005 mm in diameter and coarser fractions) shows that they contain large amounts of mica, sericitization feldspars, a very high content of the heavy-fraction minerals, and a high content of carbonates. This shows that the irrigation sediments contain considerable contents of plant nutrient elements, considering that the mineral portion of the sediments is weathered little. The quartz-feldspar ratio is low, 1.2-1.3 (Table 6).

As we know (8), the narrower this ratio, the higher is the fertility of the deposits and the soils.

As was noted, there is very little information in the literature on the mineralogical composition of soils and suspensions. Most of the publications (8, 9, 14, and others) present

Table 2

Particle-size analysis of the suspension of Amu-Dar'ya River and various sections of the irrigation system, % of carbonate- and salt-free sample

Sampling place and time	Particle diameter, mm						Total parti- cles <0.01 mm in diam.	Carbonates (including loesses)
	Particle diameter, mm							
	> 0.25	0.25—0.10	0.10—0.05	0.05—0.01	0.01—0.005	0.005—0.001	< 0.001	
Amu-Dar'ya River, Parlytau settlement, June 2, 1954	0.11	0.07	27.59	17.14	25.09	30.01	72.24	24.86
" " Kyzkytken, head, May 1, 1955	—	0.93	44.31	14.86	20.84	20.37	54.07	24.84
" " May 12, 1955	—	0.14	51.59	15.77	42.82	19.70	48.29	25.07
" " June 23, 1955	—	0.04	37.46	8.89	26.60	23.85	62.34	24.30
Kyzkytken canal, head, May 26, 1954	0.03	0.09	3.74 36.73	16.63	20.80	21.98	59.41	25.15
" " " May 1, 1955	—	1.49	50.87	10.89	16.90	19.81	47.60	28.50
" " " May 12, 1955	—	0.06	57.77	12.85	12.70	16.85	42.40	22.80
" " " June 25, 1955	—	0.01	49.00	9.84	18.60	22.50	50.94	22.80
Kyzkytken canal, town of Nukus, May 26, 1954	—	—	1.11 30.69	20.19	22.78	25.24	68.21	26.69
Kegeyli canal, head, May 27, 1954	0.04	0.04	1.98 35.35	16.78	21.05	24.76	62.59	24.80
" " " May 2, 1955	—	0.04	49.86	10.70	18.34	21.11	50.85	18.00
" " " May 12, 1955	—	0.87	41.00	15.35	19.75	23.09	53.19	24.30
Kegeyli canal, 7 km from town of Khalkabada, June 29, 1954	0.01	0.03	1.50 38.45	14.54	21.90	23.57	60.01	24.89
" " " " May 3, 1955	—	1.64	50.27	9.26	18.81	20.62	48.09	31.1
" " " " May 13, 1955	—	0.13	43.84	14.45	19.40	22.53	56.43	25.70
Kegeyli canal, town of Chimbaya, May 30, 1954	0.04	0.04	0.44 39.30	14.68	21.52	23.98	60.18	24.94
" " " " May 4, 1955	—	1.10	46.50	13.25	19.22	19.69	52.16	23.8
" " " " May 13, 1955	—	0.14	38.31	18.95	19.90	22.77	61.62	23.40
Ava-Dzhab May 6, 1955	—	0.01	37.28	18.25	20.08	24.50	62.83	24.12
Madzhul'-Dzhab reservoir May 31, 1954	0.01	—	0.16 24.45	18.30	26.08	30.99	75.37	25.31
" " " May 7, 1955	—	—	19.2	11.6	35.90	33.30	80.80	23.93
" " " June 20, 1955	—	—	15.12	6.48	39.00	39.40	84.88	23.78

Table 3

Total chemical analysis of the suspension of Amu-Dar'ya River and canals, % of absolutely dry material

Sampling location	Hygroscopic water, %	Loss on ignition	CO ₂	SiO ₂	SO ₃	P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	MnO	K ₂ O	Na ₂ O	TiO ₂	Molecular ratio			Particle diameter >0.001 mm
															SiO ₂ /Al ₂ O ₃	SiO ₂ /Fe ₂ O ₃	SiO ₂ /R ₂ O ₃	
Amu-Dar'ya River, Par-lytau settlement	1.95	9.04	8.04	49.75	0.65	0.14	14.04	5.80	12.30	3.29	0.11	3.23	1.39	0.35	6.01	22.81	4.76	30.01
Kyzkytken canal, head	1.72	10.87	8.31	51.26	0.24	0.14	11.84	6.17	11.90	2.71	0.09	2.66	1.43	0.35	7.28	22.09	5.48	24.85
" town of Nukus	1.86	10.28	8.06	50.10	0.34	0.14	12.13	6.65	12.40	3.15	0.12	3.14	1.38	0.38	7.01	20.05	5.19	25.13
Kegeyli canal, head	1.73	11.00	8.30	50.88	0.27	0.14	12.56	6.47	12.00	3.22	0.12	2.24	1.46	0.38	6.87	21.94	5.23	24.78
Kegeyli canal, 7 km from town of Khalkabada	1.78	9.40	8.15	51.46	0.60	0.15	12.30	6.17	12.40	3.33	0.12	2.68	1.63	0.38	7.06	22.07	5.08	23.38
Kegeyli canal, Chimbaya (town)	1.77	11.00	8.15	50.56	0.31	0.13	12.59	6.49	12.50	2.39	0.12	1.75	1.64	0.38	6.82	21.04	4.97	23.85
Manzhul' - Dzhab reservoir	1.76	10.31	8.31	48.86	0.29	0.12	12.80	7.13	12.20	3.37	0.12	3.04	1.50	0.35	6.47	18.23	4.78	30.83

Table 4

Data on total (abbreviated) chemical analysis of the suspensions and loess parent material, % of the ignited carbonate-free substance

Sampling location	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	CO ₂	SiO ₂ /Al ₂ O ₃	SiO ₂ /Fe ₂ O ₃
Kyzkytken canal intake	63.82	7.68	14.86	1.57	3.37	3.68	1.78	8.31	7.28	22.09
Kegeyli canal, 7 km from town of Khalkabada	63.39	7.64	15.24	2.42	4.42	3.32	2.02	8.45	7.06	22.07
Manzhul' - Dzhab reservoir	60.89	8.88	15.95	1.96	4.20	3.78	1.87	8.31	6.47	18.23
Profile 2B, D, 1958, loess from a depth of 155-165 cm	71.59	5.72	13.65	3.18	2.24	1.93	2.61	8.35	8.90	33.10
Profile 140 I. H. 1938, loess from a depth of 130-140 cm	68.52	6.38	13.68	2.15	1.66	1.55	4.99	11.33	8.50	28.5

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Table 5

Exchange capacity and composition of adsorbed cations of the suspended sediments of the Amu-Dar'ya River and canals

Sampling location	Exchange capacity, meq	Adsorbed cations, meq			In % of total meq		
		Ca+Mg	K	Na	Ca+Mg	K	Na
Amu-Dar'ya River, Parlytau settlement	9.85	7.20	1.35	1.30	73.09	13.71	13.20
Kyzkytken canal, head	8.90	6.30	1.99	0.61	70.79	22.36	6.85
Kyzkytken canal, town of Nukus	8.96	6.85	1.46	0.65	76.45	16.30	7.25
Kegeyli canal, head	9.48	6.91	1.66	0.91	72.89	17.51	9.60
Kegeyli canal, 7 km from town of Khalkabada	8.84	5.82	1.76	1.26	65.84	19.91	14.25
Kegeyli canal, town of Chimbaya	8.29	5.98	1.35	0.96	72.14	16.23	11.53
Manzhul'-Dzhab reservoir	11.08	8.84	1.46	0.78	79.78	13.18	7.04

ly the mineralogical composition of the particle diameters >0.01 mm. In the suspensions the various sections of the irrigation system, these constitute about 50% of a sample, salt-free and carbonate-free. The remaining part of the sediments is not analyzed. Here usually only percents of each fraction are calculated, at best, of the heavy and light fractions, but not of the sediments as a whole, while the fractions sometimes constitute only tenths of a percent. For the same reason we may not give average data on the content of the individual minerals obtained by dividing the total by the number of components (9). Average data may be calculated only from the average weight %, i. e., by taking into account the content (%) of each fraction. To judge the mineralogical composition of sediments as a whole, the fine fractions must also be analyzed, and by different methods, such as x-ray and thermal methods.

We made a mineralogical analysis of the suspensions (0.01-0.005 mm in diameter andarser). The content of the individual minerals (Table 6) was calculated in % of the fraction (numerator) and of the sediments as a whole (denominator).

The low adsorption capacity of the suspensions of Amu-Dar'ya River (1) is a result of the high proportion of hydromica in the clay fraction.

Our studies in the different parts of the irrigation system show that the most significant variations in the chemical and mineralogical composition of the sediments are observed when the analytical data for the head and peripheral sections are compared. This results

from the increasing particle weight of the sediments and the differentiation of the minerals according to density as they move along the irrigation system. This situation reduces the amount of quartz in the sediments of the peripheral parts of the irrigation system, a fact borne out fully by the data of chemical analysis (Table 3). The data show a relative decrease in the content of silica and some increase in the amount of sesquioxides as we go from the head to the periphery of the system.

Irrigation water carries an enormous amount of suspension containing considerable quantities of plant nutrients to the fields. The data in Table 7 show that, at an irrigation rate of 10,000 m³/ha, the water of Amu-Dar'ya River carries more than 36 metric tons of suspended materials to the field annually. This includes 600-1200 kg of total potassium (K₂O), of which 30 kg is available; about 50 kg of total phosphorus (P₂O₅), of which 0.7 kg is available; more than 4,000 kg of calcium; and large quantities of such elements as manganese (MnO) and titanium (TiO₂). In addition, a considerable portion of the plant nutrients is dissolved in the water. At the same irrigation rate, irrigation water from the Amu-Dar'ya annually carries to the fields up to 60 kg of potassium, 8-10 kg of phosphorus, over 200 kg of water-soluble humus, and up to 700 kg of calcium per hectare in solution. We may conclude from these data that the suspensions studied are quite fertile and that waters of the Amu-Dar'ya are highly nutritive.

There are references in the literature (13) to the experiments conducted by Korsak-Egert, Bukinich, and Ridiger, which fail to show that the sediments have value as fertilizers. In

Table 6

Mineralogical composition of suspensions on May 26-31, 1954

Minerals	Kyzkytken canal, head					Manzhul'-Dzhab reservoir				
	Diameter of fraction, mm									
	>0.25	0.25-0.1	0.1-0.05	0.05-0.01	0.01-0.005	>0.25	0.25-0.1	0.1-0.05	0.05-0.01	0.01-0.005
Light fraction (particle density <2.8)	93.90	77.50	89.95	93.92	94.47	Fraction lacking	100.00	81.71	94.22	92.16
Plant and carbonaceous fragments	0.70 ^a	1.00	0.20	—	0.12		2.00	—	1.34	—
	single grains	single grains	0.01	—	0.02		single grains	—	0.33	—
Clay aggregates	66.50	13.50	2.01	0.84	—		88.00	4.56	1.30	—
	0.02	0.01	0.08	0.31	—		0.01	0.01	0.32	—
Quartz	8.0	13.00	39.62	43.62	—		3.00	21.60	33.48	—
	sngl.grs.	0.01	1.48	16.02	{ 58.26 ^b 9.69 }		sngl.grs.	0.03	8.19	{ 59.82 ^b 10.95 }
Feldspars	13.70	11.00	29.89	33.51			6.00	46.12	40.30	
	single grains	0.01	1.12	12.31	—		single grains	0.07	9.85	—
Mica and hydro-mica	1.00	37.00	6.79	15.41	34.41		1.00	9.42	16.83	31.77
	single grains	0.03	0.25	5.66	5.72		single grains	0.02	4.11	5.81
Chlorite	—	2.00	0.14	0.24	0.98		—	—	0.47	0.57
	—	single grains	0.01	0.09	0.15		—	—	0.11	0.10
Rock fragments	4.00	—	11.30	—	—		—	—	—	—
	sngl.grs.	—	0.42	—	—		—	—	—	—
Phytoliths	—	—	—	0.30	0.70		—	—	0.50	—
	—	—	—	0.11	0.12		—	—	0.12	—
Heavy fraction (particle density >2.8)	5.8	22.00	10.03	6.00	5.52		—	18.30	5.78	7.83
Amphiboles	—	—	4.80	2.90	0.71		—	3.17	2.28	0.57
	—	—	0.18	1.07	0.12		—	sngl.grs.	0.56	0.10
Epidote, zoisite	5.8	11.00	1.20	2.53	2.52		—	7.80	1.55	3.43
	sngl.grs.	0.01	0.04	0.98	0.42		—	0.01	0.38	0.63
	—	9.00	3.72	0.44	1.10		—	6.11	0.89	1.27
	—	0.01	0.14	0.16	0.18		—	0.01	0.22	0.23
Ores	—	—	—	—	—		—	—	—	—
Rutile, titanite, turmaline, zircon, apatite, garnet, etc.	—	2.00	0.31	0.13	1.19		—	1.22	1.06	2.56
	—	single grains	0.01	0.05	0.20		—	single grains	0.26	0.47
Ratio quartz feldspars	0.6	1.2	1.3	1.3	—		0.5	0.5	0.8	—
Content of carbonates and other losses in treatment with HCl, in %	—	25.15	—	—	—	—	25.31	—	—	

^aNumerator is % of the fraction, denominator is % of the whole sample.^bThese figures are the sum for quartz and feldspars.

FERTILITY OF IRRIGATED SOILS

Table 7

Quantities of mineral substances delivered to the fields in irrigation, kg/ha
(irrigation rate 10,000 m³/ha)

Sampling location	Suspensions									
	Total nitrogen	Total humus	Total P ₂ O ₅	Available P ₂ O ₅	Total K ₂ O	Available K ⁺	Total CaO	CaSO ₄ 2H ₂ O	MnO	TiO
Amu-Dar'ya River, Par-lytau settlement	19	266	40	0.72	1163	19	4428	61	40	126
Kyzktyken canal, head	22	252	50	0.72	1066	28	4284	52	32	126
Kyzktyken near Nukus township	18	241	50	0.86	1130	20	4464	61	43	137
Kegeyli canal, head	19	259	50	0.58	806	23	4320	57	43	137
Kegeyli canal, 7 km from Khalkabada	19	256	54	0.58	965	25	4464	56	43	137
Kegeyli canal, town of Chimbaya	18	238	47	0.72	630	19	4500	45	43	137
Manzhul'-Dzhab reservoir	21	284	43	0.72	1194	20	4392	50	43	126

Irrigation water

Sampling location	Solid residue	Total alkalinity as HCO ₃	Cl ⁻	SO ₄ ⁼	P ₂ O ₅	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	Humus
Amu-Dar'ya River, Par-lytau settlement	4240	910	720	1230	9	590	90	50	440	not det.
Kyzktyken canal, head	4720	910	840	1430	10	680	130	60	510	163
Kyzktyken near Nukus township	4720	910	840	1400	8	650	80	50	510	not det.
Kegeyli canal, head	4720	940	840	1400	8	650	80	60	510	142
Kegeyli canal, 7 km from Khalkabada	4600	1060	800	1180	8	680	110	60	480	225
Kegeyli canal, town of Chimbaya	4200	910	800	1200	8	600	100	50	480	not det.
Manzhul'-Dzhab reservoir	4080	890	700	1270	8	600	90	50	480	"

Note: Available phosphorus was determined by the carbonate extract method as modified by the Soyuz NIKhI (Machigina). All-Union Scientific Research Institute of Cotton Growing.

These experiments 10%-20% of fresh clay was added to containers of Kara-Kum sand or the sand was irrigated with water containing clay from the Amu-Dar'ya. No difference was observed in the development of corn in control pots containing pure Kara-Kum sand, or the added Amu-Dar'ya clay in any proportion. In our opinion this is explained as follows.

Kara-Kum sands are old alluvial deposits of the Pra-Amu-Dar'ya (10). It is possible that under the influence of a long period of weathering and high temperature in the upper layers of the soil (reaching 60°-65°C) the plant nutrients in the sand had become more easily available to the plants than in freshly deposited Amu-Dar'ya sediment. Some investigators (3, 4) have noted that organic matter, nitrogen, and phosphorus in the soil become more soluble

after drying and ignition of the sediments. This explains why farmers on the kolkozoes prefer to use the older, more weathered sediments as fertilizers. Clay was also applied in a very small quantity in these experiments, particularly in the case of simple irrigation with water from the Amu-Dar'ya; it could not show a positive effect, and thus cannot be considered a fertilizer in the full sense of the word. Here the amounts used must be much larger than when mineral fertilizers are used.

Pot experiments by A. A. Budakova on siero- zem of the Pakhta-Aral sovkhos (under alfalfa), to which suspensions of the Amu-Dar'ya River were added as fertilizers, showed (Fig. 1) that in the first season of growth the suspension of Amu-Dar'ya is no less fertile than the Pakhta-Aral siero- zem after alfalfa. Addition of various



Fig. 1. - Effect of addition of Amu-Dar'ya suspension to sierozem on growth of barley.

1. Soil; 2. Soil + 10% suspension; 3. 30% suspension; 4. 50% suspension; 5. 80% suspension; 6. 100% suspension.

amounts of suspensions to the sierozem always showed a positive effect on the growth of barley. Only on pure suspensions did plant growth drop off somewhat, but it did not drop below the growth of barley on soil without suspensions.

In 1956, Budakova repeated these experiments in order to evaluate the fertility of the Amu-Dar'ya suspensions. From the data of Table 8 we see that our conclusion concerning the fertility of the Amu-Dar'ya suspensions is fully confirmed.

the suspensions as well as the Amu-Dar'ya River delta soils need added mineral and organic fertilizers, primarily nitrogen and phosphorus.

What occurs in sediments during soil formation? In Table 9 data are given from analyses of two soils: a very young meadow soil developed under reed vegetation (Profile 433) and a considerably older steppe-forming takyr soil (Profile 445) that is almost without vegetation.

Table 8

Results of plant-growth experiments with suspension from Amu-Dar'ya River (Soil — Takyr-like sierozem of the Chimbaya Experimental Station) Two replicates

Treatments	Yield of dry mass, in g, and devia. from the average	Dry mass %
Soil + NP	7.2 ± 0.0	100
Soil + NP + 10% suspension	13.6 ± 1.1	190
Soil + NP 30% suspension	14.1 ± 0.9	196
Soil + NP 50% suspension	10.3 ± 1.1	143
Soil + NP 70% suspension	10.5 ± 0.7	146
Suspension + NP	8.2 ± 0.0	114

Thus, the suspension is not just inert material and does not lower the fertility of irrigated soils; on the contrary, it improves conditions for plant growth. But for better crops

Young meadow soils differ from immature sedimentary deposits in their higher content of humus (about 2%) and nitrogen (up to 0.1%), some accumulation of sesquioxides and a

Table 9
Total chemical analysis of soils

Depth, cm	In % of an absolutely dry sample, carbonate-, humus-, salt-, gypsum-free sample										Molecular ratio			Particle diam. <0.001 mm	% hu- mus (accord- to Ty- urin)	% ni- tro- gen	Exch. capa- city, meq	In % of exchange capacity		
	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	R ₂ O ₃	CaO	MgO	P ₂ O ₅	K ₂ O	Na ₂ O	CO ₂	SiO ₂	SiO ₂	SiO ₂							
											Al ₂ O ₃	Fe ₂ O ₃	R ₂ O ₃							
Soils of dried swamps transitional to meadows, profile 433																				
0-10	56.38	7.04	20.48	28.37	0.68	4.95	0.47	2.80	2.23	6.00	4.79	21.47	3.91	56.25	1.93	0.12	16.35	91.00	4.90	4.10
20-30	60.19	6.67	13.60	22.39	4.03	4.44	0.18	2.07	2.52	6.14	7.68	24.05	5.84	32.06	1.70	0.088	11.48	95.92	1.65	2.43
Taky, transitional to zonal soils, profile 445																				
0-2	68.67	4.96	14.51	20.53	0.47	2.93	0.43	2.35	2.56	6.20	7.50	35.47	6.43	27.83	0.51	0.082	8.17	81.64	7.22	11.14
2-9	60.75	7.03	16.72	25.07	1.26	3.97	0.13	2.72	1.91	6.70	6.30	22.91	4.94	44.22	0.50	0.039	12.01	85.53	3.17	11.25
9-23	57.60	7.10	18.08	26.32	1.70	4.43	0.13	3.53	1.88	7.00	5.52	21.56	4.39	43.53	0.52	0.039	12.78	96.63	1.88	1.40
23-46	66.61	5.46	12.98	19.28	2.59	3.35	0.16	1.73	2.56	7.50	8.92	34.34	7.11	not det.	0.23	0.011	not determined			

corresponding decrease in silica content in the surface horizon. This leads to higher exchange capacity and the increased importance of calcium and magnesium in the adsorption complex.

As the pot experiments of Budakova showed, the suspensions are better supplied with nitrogen and calcium than these soils. Evidently the reeds (Profile 433), in spite of their rapid and almost complete mineralization as green manure, deplete the soil of available nutrients.

Steppe-forming taky soils are poor in organic matter and nitrogen in comparison with recent deposits. This results from the almost total lack of higher vegetation and the continuous erosion by water and wind of soil particles and algae films from the upper horizon. The highly dispersed upper soil horizon, resulting from the high concentration of exchangeable sodium, contributes to this process. The upper crust of takyrs differs from irrigation sediments in the loss of the sesquioxides, calcium, magnesium, and partly, potassium — as well as in the relative accumulation of silica. The accumulation of ferrous compounds under the crust results from the activity of algae, which are almost the sole source of organic matter here.

Opinions differ in the literature on the question of whether suspensions should or should not be carried to irrigated fields. These reflect basically two points of view — 1) the suspensions should not be carried to the fields because they clog the irrigation canals and cleaning these annually is very expensive, and 2) since the suspensions are fertile, they should be carried to the fields.

On the basis of data from the literature and from our laboratory experiments we have concluded that irrigation sediments have a very positive effect on the field topography, by raising its level, and also on soil fertility. Therefore, the suspension should be carried to the fields, except for the coarsest fractions, which are poor in plant nutrients. The suspension can also be used to level fields for adding fine materials to sandy soils and canals; and the coarser sediments can be utilized to improve the fine-textured soils.

We must remember that the suspensions have a different particle-size distribution in various parts of the irrigation system, and when applied their effects will vary, especially on the physical properties of the soils and on their chemical and mineralogical composition. There is a need for a differential approach to the addition of suspensions, adjusting the fractional ratio by operational means.

In conclusion it must be stressed that the movement of suspensions in streams is a very complicated process determined by many fac-

tors. Naturally then, data on the distribution of suspensions and their chemical and mineralogical characteristics obtained at different times and by varying methods cannot be compared without considering all the factors affecting this process. It is evident from our data that the particle-size as well as the chemical and mineralogical composition of the suspensions varies, with both time and location. Therefore, one should be very careful in comparing the composition of the suspensions of different streams, observing closely the similarity of conditions under which the samples were taken. This is particularly important when comparing the results of many years of investigations. In older studies these factors were not considered sufficiently, and not much attention was paid to the methods of investigation (taking the samples, calculations, etc.); even now, we do not have uniform methods of calculation, especially for mineralogical analysis.

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THE EFFECT OF GRASS ON THE PHOSPHATE REGIME OF THE SOIL

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Apatites are the primary phosphates in the soil, but during soil formation other forms of phosphates also accumulate. In this transformation of phosphates an enormous part is played by vegetation, in particular by mixed grasses and legumes.

In 1947-1950 we studied the forms of phosphates in different fields under crop rotation; the results are given in this paper. The phosphates were studied by the method worked out by (3).

In our earlier experiments (3) we established the presence of phosphorus in sierozems, predominantly in mineral forms. Organic phosphates, even with systematic annual application of manure for 13 years, did not exceed 1%. Of the mineral phosphates, 91%-94% were in the form of calcium compounds, extractable with 0.2 N $C_2H_4O_2$, and the rest are extracted with 0.2 N HCl. Evidently, these are compounds of phosphorus with sesquioxides.

In the soil samples studied between 1947 and 1950, we determined, in addition to total phosphorus, those phosphates extracted by citric and hydrochloric acids as well as the organophosphate content. In this paper more attention will be given to the determination of organophosphates in the soils.

For our study we used samples of soils under cotton-alfalfa crop rotation at the Ak-Kavak Experiment Station. The soils studied were under grasses for different lengths of time and then under cotton. The soils were analyzed after the rootlets visible to the naked eye had been removed. The results of the analyses are given in Table 1.

The data presented confirm the results of our earlier studies and give us a basis for assuming that fields with alfalfa plowed up at different ages contain different quantities of organophosphates. Even though the amount of organophosphates after the first year of alfalfa shows almost no difference from that

in fields single-cropped to cotton, in the second (and especially in the third) year the organophosphate content increases fairly sharply. In comparison with the plow layer, the layer below is less rich in humus and hence contains less organophosphates.

The increased organophosphate content in the soil, as the age of the plowed-up alfalfa rises, evidently is related to the continuing process of death and humification of its roots and to some extent of its stubble. The rapid humification of organic material in fields rotated to grasses is accompanied by biological assimilation of phosphorus. This microbiological process and the increased root and aerial growth of the alfalfa, wherein much organic phosphorus accumulates, is the reason for the decrease in available forms of phosphorus usually observed in soils under alfalfa that have been under cultivation for a long time.

As the data of Dobrotvorskaya and Gornaya (1) and those of Kononova and Lagunova (5) show, the organic material of alfalfa roots is relatively mobile and is easily acted upon by microorganisms. The humification is particularly vigorous in the soils of Central Asia, where microbiological activity is extremely high.

As the data from the Ak-Kavak Experiment Station show (6), after the first year of cultivation of forage crops, there was humification of 73%-99% of the organic material of root and stubble residues of alfalfa crops, and of a grass-alfalfa mixture. In this connection, there was a fairly distinct decrease in the organic carbon content of fields under crop rotation, depending on the length of time alfalfa had been plowed up.

The organophosphate content in the soil, besides depending on the age of the alfalfa, also is a function of the length of time the alfalfa has been plowed up and cotton has been grown in rotation. The data for studies of this are given in Table 2.

Table 1

Phosphate content in the soil of fields under cotton-alfalfa rotation

Plots	Depth, cm	Total phosphorus removed from the soil, mineral and organic forms, mg/kg of soil	Organophosphates amount to	
			mg P_2O_5 /kg of soil	% of all forms removed
Cotton after three-year alfalfa	0-20	1624	330	20.2
Same	20-40	1541	220	20.7
Plowed, after two-year alfalfa	0-20	1640	307	18.7
Same	20-40	1498	270	18.1
Plowed, after one-year alfalfa	0-20	1683	289	17.2
Same	20-40	1433	181	12.7
Continuously cropped to cotton	0-20	1926	254	13.7
Same	20-40	1907	238	12.5

Table 2

Content of different forms of phosphates under cotton on fields under crop rotation at the Ak-Kavak station (0-20 cm depth)

Plot No.	Land use	Mineral and organic forms of phosphorus removed from the soil, mg/kg of soil	Organophosphates amount to	
			mg P ₂ O ₅ /kg of soil	% of all phosphates removed
Nine-year cotton-legume rotation (3 years alfalfa and 6 years cotton)				
65	Plowed mixed grasses	1646	339	20.6
14	Plowed alfalfa	1774	322	18.1
14	Plowed mixed grasses	1923	322	16.7
46	Cotton,6th year after mixed grasses	1789	237	13.2
46	Cotton,6th year after alfalfa	1866	285	15.3
Six-year cotton-legume rotation (2 years alfalfa and 4 years cotton)				
58	Plowed mixed grasses	1658	289	17.4
34	Plowed mixed grasses	1880	233	12.4
34	Plowed alfalfa	1747	237	13.6
42	Cotton, 4th year after mixed grasses	1651	225	13.6
42	Cotton, 4th year after alfalfa	1876	230	12.3

As we see from the data given, the organophosphates were less in areas where cotton had long been grown than where alfalfa or mixed grasses had recently been grown. On

the other hand, land plowed after three-years of grass was somewhat richer in these forms of phosphates than soils of similar fields under rotation with a two-year stand of grass.

PHOSPHATE REGIME

The difference in the content of organic phosphates in the soils from the fields under crop rotation depends on the length of the period since plowing up of the forage crop.

The first stages of intense humification of clover and alfalfa residues (Zhorikov [2] and Andraimov [6]) are accompanied by biological assimilation of nitrogen; our data, obtained from laboratory composting of soil and bound alfalfa hay (1 kg of soil with 20 g of alfalfa hay and moisture kept at 60% of full moisture capacity), indicate that the phosphorus in the soil also depends on biological activity (Table 3).

when the grasses are plowed up. The basic explanation for the effectiveness of phosphorous fertilizers in the first years after grasses are plowed up is found in the unfavorable ratio of the available forms of nitrogen and phosphorus.

Beginning with the turning under of sod, and in conjunction with the decreased biological assimilation of phosphates (as attested by the reduced organophosphate content in the soil), there is an increase in the availability of soil phosphates in a 1% ammonium carbonate extract.

Table 3

The effect of alfalfa organic matter on the availability of phosphates in the soil (P_2O_5 in mg/kg of air-dry soil)

Treatment	Length of composting, days			
	15	45	90	150
Soil composted with alfalfa	Slight	7.9	14.2	38.4
Soil composted without alfalfa	6.7	6.7	10.0	12.4

The data show that in the first period of composting there was a decreased availability of phosphates related to their biological assimilation, and this lasted 1-1.5 months. Hereafter the organic material began to show a positive effect on the availability of the phosphates, and this became particularly strong toward the end of the experiment. Similar data were obtained by Zhorikov (2) in the composting of soil with alfalfa roots.

Thus, in the first period after alfalfa is plowed up there is a biological fixation not only of nitrogen but also of phosphorus. The increased availability of phosphates as a result of the decomposition of the organic matter of alfalfa is due primarily to the fact that in the decomposition process mobile organophosphates are released as well as acid products of root decomposition (7), and these, interacting with the soil phosphates, convert them into an available form. Microbiological activity, stimulated by the organic matter of the alfalfa, leads to cause the same thing.

Since the roots and residues contain more nitrogen than phosphorus, the first of these elements accumulates in the soil in an available form more abundantly than the second

Even though alfalfa harvested at the rate of 100-300 ctnr/ha of dry hay removes about 40-180 kg of phosphorus from the soil in three years, we must still acknowledge its favorable effect on the phosphate regime of the soil. Thus, herbage in crop rotation is an important factor for increasing the mobility and availability of the phosphates contained in the soil and added thereto.

In closing let us mention that turning under grasses into soil after a definite number of years is a necessary condition for improving the phosphate nutrition of the basic crop rotation — cotton.

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THERMAL PROPERTIES OF SOIL AS A FUNCTION OF ITS MOISTURE AND COMPACTION

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The thermal conditions of soil influence the biological processes within it and the physiological processes in plants.

Various agricultural practices, such as irrigation, rolling, depth of plowing and cultivation, can change the thermal conditions of soil within certain limits. However, to determine a purposeful method of soil cultivation it is first necessary to know its thermal properties, which are expressed by its thermal characteristics: heat conductivity, thermal diffusivity and volumetric heat capacity.

Much has been written about the role of thermal characteristics of soil to attain the necessary thermal conditions by means of soil cultivation (8, 12, 13), but the regularity of their variation as a function of soil properties has not been established.

We have determined the thermal characteristics of the southern chernozem and certain other physical properties which influence them.

On the basis of particle size analysis the investigated soil belongs to fine-textured clays. Particle density varies from 2.5-2.7 g/cc and bulk density from 1.2-1.5 g/cc in the layer between 0-100 cm. Moisture constants were determined by means of the drying rate, following the method of F. E. Kolyasev. These have been confirmed and completed since then by field and laboratory tests. Maximum hygroscopicity is 11%, wilting moisture 11%, growth-retarding moisture 18%, field moisture capacity 27%, and saturation moisture capacity 41% of the weight of the dry soil.

This paper gives the results of investigation of the thermal characteristics of the southern chernozem in relation to soil moisture and compaction. The experiment was carried out using soils with disturbed structure, since, as we planned the problem, it was necessary to vary the compaction while moisture remained constant, and vary the moisture while compaction remained constant.

This is not possible under field conditions.

During the last years Soviet specialists have worked out many methods of determining thermal characteristics of soils (9, 11). We have determined the coefficient of thermal diffusivity by the method of Kondrat'ev (7) based on the principle of the steady state for a sample of cylindrical shape.

In the tests, compaction ρ varied from 1.1-1.5 g/cc by 0.1, and moisture W was under the following conditions: oven-dry, air-dry, 10%, 20% and 25% moisture by weight. The coefficient of heat diffusivity K was measured on more than 100 soil samples of the plowed layer. Similar measurements were carried out for the soil layer between 80-100 cm. These K values differed from those for the plowed layer within the experimental error. It is possible to conclude that, for southern chernozem, the coefficient of thermal diffusivity under the same compaction and moisture, in practice, does not vary until the parent material is reached. This may be attributed to the fact that soil dispersion in this layer is uniform. Thus, to explain the relationship of K to moisture and compaction we have limited ourselves to analysis of the data from the plowed layer. In Table 1, mean values of the experimental data are given with varying moisture contents and compaction.

In Figure 1 these data are represented graphically.

Volumetric thermal capacity can be calculated by means of the equation

$$C_p = \left(0.2 + \frac{W}{100} \right) \rho,$$

where C is volumetric thermal capacity, W moisture, ρ compaction and 0.2 represents the specific heat of fine clay loams.

Volumetric thermal capacity increases linearly with increasing moisture and compaction.

Table 1

Coefficient of thermal diffusivity of the southern chernozem
at various moisture and compaction levels

Mois- ture, %	Bulk density, ρ				
	1.1	1.2	1.3	1.4	1.5
0	0.0012	0.0013	0.0015	0.0016	0.0017
4	0.0013	0.0015	0.0016	0.0017	0.0017
10	0.0023	0.0026	0.0027	0.0030	—
20	0.0033	0.0035	0.0038	0.0041	0.0043
25	0.0031	0.0033	0.0035	0.0037	0.0039

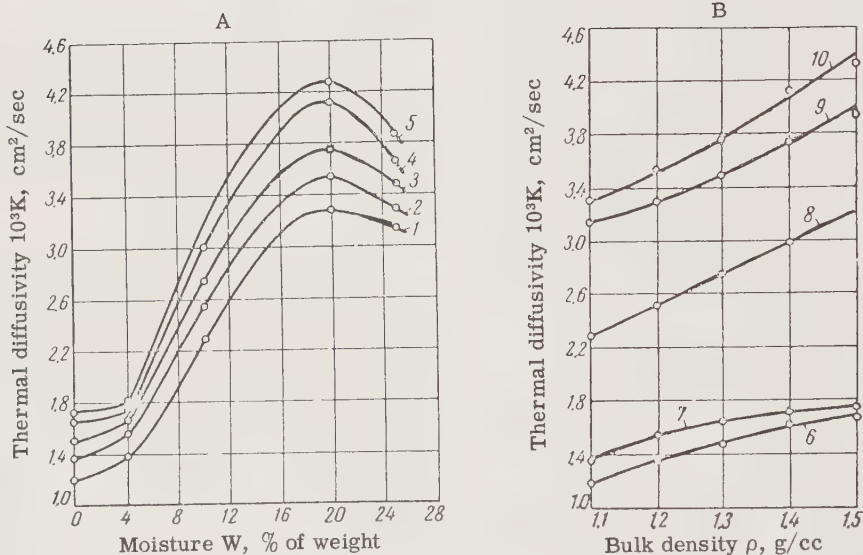


Fig. 1. - Correlation of the thermal diffusivity coefficient with moisture at various levels of compaction (A) and with compaction at various levels of moisture (B).

1 — $\rho = 1.1$; 2 — $\rho = 1.2$; 3 — $\rho = 1.3$; 4 — $\rho = 1.4$; 5 — $\rho = 1.5$; 6 — $w = 0\%$;
7 — $w = 4$; 8 — $w = 10$; 9 — $w = 25$; 10 — $w = 20\%$

The coefficient of heat conductivity λ is calculated by means of the equation $\lambda = K\rho$. The resulting data are given in graphic form in Figure 2.

The coefficient of heat conductivity for any moisture and compaction level may be calculated by our empirical formula:

$$\lambda = 10^{-3} \left[(2.1 \rho^{1.2-0.02W} 1 - 0.007(W-20)^2 + \rho^{0.8+0.02W}) \left(0.2 + \frac{W}{100} \right) \rho \right].$$

This formula is very complex and, therefore, a nomograph has been constructed (2) by means of which it is easy to determine all heat characteristics for given values of moisture and compaction and, if K , λ , and ρ are known,

it is also possible to calculate moisture.

We have also calculated the coefficient of thermal diffusivity for soils with undisturbed structure. The values obtained for K are somewhat smaller than those for soils with disturbed structure. For soil samples taken at different depths, the differences between

the values obtained for disturbed soil structure decreases with depth. While at depths of 10 and 20 cm the difference attains 11%, at the depth of 30 cm it is only 5%, which is not greater than experimental error.

THERMAL PROPERTIES OF SOIL

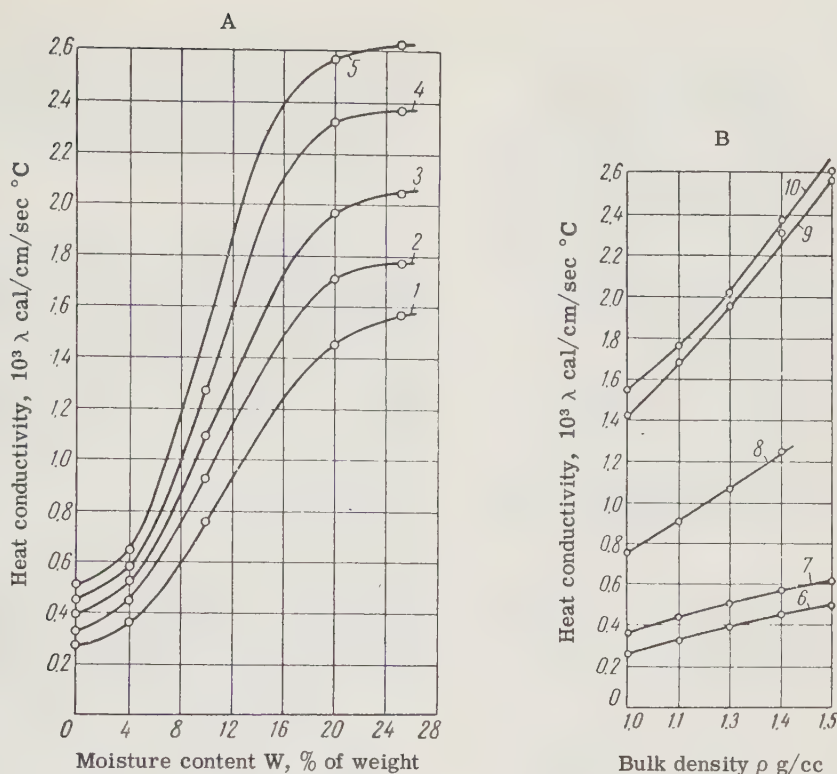


Fig. 2. - Relationship of the coefficient of heat conductivity with moisture at various levels of compaction (A) and with compaction at various levels of moisture (B).

1 — $\rho = 1,1$; 2 — $\rho = 1,2$; 3 — $\rho = 1,3$; 4 — $\rho = 1,4$; 5 — $\rho = 1,5$; 6 — $w = 0\%$;
7 — $w = 4$; 8 — $w = 10$; 9 — $w = 20$ 10 — $w = 25\%$

The defined relationships for disturbed soils may also be utilized for natural conditions.

Discussion of Experimental Results

According to Chudnovskiy (14), Dimo (3), and Kostin (10) $K = f(W)$ attains its maximum value at various moisture contents depending on the soil properties. For a fine-grained calcareous sand K maxima is found between 8%-10% moisture content, coarse-grain sand 5%-8%, and for clays 24%-28%.

The type of curves for $K = f(W)$ also varies; for sandy soil the curve is convex, for clay it is concave.

According to our data obtained from a large number of measurements with varying compaction and moisture content, K for southern Chernozem attains maxima at a moisture content of 18%-20%.

The results of our test and the data of other authors have made it possible to explain the relationship of K with moisture as determined

by various soil-moisture properties. The coefficients of heat conductivity and thermal diffusivity for a certain soil increase unevenly within the various moisture contents as moisture increases. This confirms the uneven character of heat transfer at the various moisture contents.

The hypothesis of the relationship between the mode of heat transfer and the forms of soil water was formulated by Chudnikovskiy (14), and also by Dimo (4). In dry soil, as in a disperse system of solids and gas, the heat flow does not advance in a continuous front, but by separate streams following the shortest distance between the particles (1). In moist soil, as in a three-phased medium, heat transfer takes place through solid particles, water, and air. The magnitude of heat conductivity depends on the shape, type, and size of contacts of separate particles, and on the amount of water and air between them. Therefore, to understand the manner of heat transfer in moist soil, it is necessary to know the laws of bonding of soil particles with water at different moisture contents. The problem as posed has no single answer and this makes it

even more difficult to explain the nature of the heat transfer in soil.

In order to clarify the relationship of the thermal characteristics with soil moisture, we have availed ourselves of the theory of forms and movements of moisture in soils formulated by Kolyasev (5) and known as the theory of differential soil moisture. Kolyasev outlined the principal mechanisms of soil moisture movement (6). Essentially, it divides all soil moisture on the basis of physical causes which produce the movement of water under various moisture conditions and it also relates the moisture content to soil particles.

Five basic mechanisms of movement of soil moisture are recognized: diffusion, film, film-meniscus, capillary, and gravitational (5). Such a concept of soil moisture movement makes it possible to formulate a hypothesis of heat transfer in moist soil at different moisture levels.

The relationships $K = f(\rho w)$ and $\lambda = \phi(\rho w)$, obtained in our experiment, may be explained by constructing a diagram in which heat transfer is related to moisture movement as influenced by moisture content and compaction of soil.

As compaction increases, the coefficients of thermal diffusivity and thermal conductivity increase; the mode of the increase being dependent on moisture content.

In oven-dry soil K and λ increase as compaction increases, but at a higher rate when compaction values are low; when compaction values are higher their increase tends to taper off (Figs. 1, 2). In such a soil, heat transfer takes place mainly through contacts between soil particles. As compaction increases, a limit to the packing is being reached. Similar curves for K and λ will be obtained for air-dry soil, except that their values will be considerably greater than in oven-dry soil, since absorbed water improves the contacts somewhat.

At 10% moisture (film mechanism of water movement) K and λ show a linear increase as compactness increases, and their values grow sharply in comparison with those for air-dry soil. At this moisture content, water takes part in heat transfer; water forms bridges between the particles through which heat transfer takes place. At the 20% moisture level the film-meniscus mechanism of moisture movement passes into the capillary. Here the values for K and λ continue to increase as compaction increases. They attain their maxima at high compaction. The increase in compaction brings about a closer packing of particles. As a result of this, the length of the bridges decreases and their width increases. Thus, thermal resistance decreases. More-

over, through compaction the amount of solid phase is increased, the thermal conductivity of which is 5 times greater than that of water. Under such conditions heat transfer does not take place by separate channels or bridges but by a continuous flow through water and the solid phase, which plays an important part in heat transfer.

At a moisture content of 25% the capillary mechanism of water movement prevails. The character of the values of K and λ , when compaction increases, is the same as at 20% moisture, but the absolute value of K for all levels of compaction is smaller. It is possible to assume that as moisture increases during this stage of capillary water movement, this water is not only a binding bridge between the solid particles but also a medium through which heat is transferred. As the amount of water increases, it begins to play a greater part in heat transfer. As a consequence, the increment in the coefficient of heat conductivity begins to taper off and approximates that of water (Fig. 2). As the volumetric thermal capacity continues to grow, the coefficient of thermal diffusivity begins to decrease with further increases in moisture content.

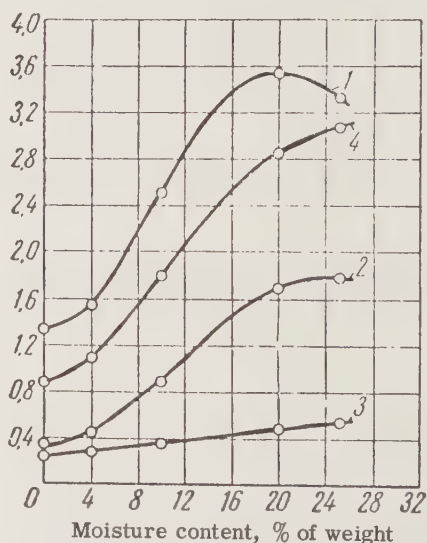


Fig. 3. - Relationship of thermal properties with moisture content at 1.2 g/cc compaction.

1. Thermal diffusivity $10^3 K$; 2. Heat conductivity $10^3 \lambda$; 3. Volumetric thermal capacity C_p ; 4. Coefficient of heat absorption $10^2 \lambda C_p$.

Thus, the coefficient of thermal diffusivity increases as moisture increases and attains its maxima at those moisture contents at which water movement in soils changes from film-meniscus to capillary. This corresponds to the moisture content at which plant growth begins

to slow down.

Each soil has its own moisture constants and this accounts for the fact that the coefficient of thermal diffusivity in different soils attains its maxima at different moisture contents. Evidently, the breaking point on the curve $K = f(W)$ for all soils corresponds to the moisture content at which plant growth begins to be retarded. It is important to keep in mind that breaking points will occur even at moistures corresponding to other soil-water constants; maximum hygroscopicity and the permanent wilting moisture. This is the task of further research which can be made while working out a method for continuous recording of moisture. At present, such a method is being perfected in the laboratories of the Agricultural-physical Institute of VASKhNIL.

Conclusions

1. The relationship of thermal characteristics with moisture and compaction is fundamental in carrying out measures of thermal improvement. Thermal diffusivity, which determines the warming of soil in depth, increases as moisture increases, until it attains a value corresponding to that at which plant growth is retarded, and, in consequence, in moisture soil the rate of temperature equalization will be greater and the warming in depth intensive. At a moisture content higher than that at which plant growth is retarded, the warming of soil is slowed and K decreases with the increase in moisture.

2. Beginning with the hypothesis of the relationship of heat transfer in moist soil with water movement at different moisture contents, we can conclude that a relationship exists between the thermal and moisture properties of soil.

3. The accumulation of experimental data on the relationship of thermal properties with moisture content in different soils, together with the determination of their moisture properties, makes it possible to give a physical basis to the theory of differential moisture, with which we have explained heat transfer in moist soil.

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SWELLING OF COMPACTED SOIL MATERIALS

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Swelling is characteristic of clay soil materials. Although there are several theories regarding the nature of soil material swelling, the two most widely held are the capillary theory and the theory of ionic layers. The capillary theory explains the swelling by internal capillary tension. Since this tension is negative within soil material, and equal to 0 on the surface, water movement must be from the surface inward until capillary tension disappears in the entire mass of soil material. Because of this, soil material swells, since the forces disappear which have held the particles together.

The theory of ionic layers is based on the assumption of a double electrical layer acting as a condenser, in which one plate is made up of the solid phase and the other of the liquid medium. The structure of the ionic layers (micelles) is interpreted in various ways. From the physical viewpoint, it is assumed that adsorption takes place at the point of contact of the two phases. According to the colloidal-chemical viewpoint, the ionic layers are manifestations of dissociation.

The second theory has been thoroughly examined by Rode (7) who concluded that dissociation in saturated soil materials plays a very minor part, since the degree of dissociation of exchange cations is represented by small percentages. For monovalent cations, dissociation is somewhat higher than for polyvalent.

The capillary theory cannot explain swelling because capillary tension is present even in soil with coarse texture (sands, sandy loams); and yet, even at low levels of saturation in sands and coarse sandy loams, the opposite phenomenon occurs, namely shrinkage. The theory of ionic layers and the "wedging" effect of thin films of water, formulated by Deriagin and his co-workers (2), permit us to attack the problem of swelling from a somewhat different angle.

Upon hydration of soil particles, the thin

films of water gradually thicken up to 10-20 times the thickness of water molecules, i. e. 30-60 Å, with a strictly polar molecule orientation in relation to the surface of the solid phase. The thickening film of water tends to distribute itself uniformly over the surface of the particle being hydrated and, at the same time, to separate the particles of soil material. Thus the wedging tension, which ultimately brings about the swelling of soil material, originates on the particle. The swelling will continue until the wedging tension is balanced by internal forces acting upon the skeleton of soil material. All overlying layers of soil and the loads formed on its surfaces, will be subjected to such forces (4).

The simplest method, justified by practice and suggested by Vasilev (1), has been utilized in investigating the swelling of soil materials.¹ The device consisted of rings 56 mm in diameter and 20 mm in height, placed in a glass container on a porous base. The amount of swelling was measured on a special indicator stage.

The investigation was carried out in the following sequence. Natural, crumply soil material was wetted to a predetermined level. The rings were filled after the soil material was kept for 15 days in a hermetically sealed container to distribute moisture more evenly throughout. The soil material in the rings was compacted to a predetermined density. Four rings were prepared simultaneously for each moisture and compaction level. The rings were then placed in containers with water for saturation; in one series of tests, without compression, and in the other series with various levels of compression. Saturation was continued until the indicator became stabilized, thus indicating that equilibrium was achieved

¹The author carried out the research in the Ukrainian Research Institute of Hydrotechnic and Amelioration. Senior laboratory assistant V. Ia. Shapran and laboratory assistant S. A. Levina participated.

SWELLING OF COMPACTED SOIL MATERIALS

Table 1

Characteristics of soil material used in the study

Object of study	Total surface area, m ² /g	MMM ^a	Separates, %			Specific weight	Humus, %	Sample No.
			sand	silt	clay			
Coarse clay loam	70.0	13.2	23.0	65.3	11.7	2.6	0.0	1
Coarse clay loam	70.4	8.6	57.5	31.6	10.9	2.6	1.1	3
Medium clay loam	133.9	15.0	7.5	74.4	18.1	2.7	0.0	6
Coarse clay loam	212.2	16.7	8.3	56.4	35.2	2.6	2.2	12
Coarse clay loam	229.2	16.4	10.3	50.3	39.4	2.7	0.0	11
Coarse clay loam	274.0	21.1	9.7	56.2	34.0	2.6	4.2	13
Coarse clay loam	275.0	17.3	11.5	59.8	29.7	2.7	0.0	7
Medium clay loam	323.0	19.9	5.9	69.8	24.2	2.6	7.6	14

^aMMM is the maximal molecular moisture

and that swelling had ceased.

A collection of samples, the characteristics of which are given in Table 1, was used in the investigation of compacted soil materials. In each experimental series of one soil material type, four levels of both moisture and compaction were used, and each test was repeated four times. Nine soil materials were investigated and 640 tests of swelling without compression were carried out. The results are shown in Table 2. The data represent the means of four tests.

Swelling of Non-Compressed Soil Materials

After each test, note was made of the absolute swelling, weight, volume, and moisture content of each sample. At the time the soil material was placed in the rings, its initial moisture level and compaction had been carefully determined. Each test, repeated four times, was taken into account only if the difference between the results (linear swelling) did not amount to more than 5%. If this condition was not obtained, the experiment was repeated. In individual determinations the difference did not amount to over 1% for moisture (absolute) and 0.05 g/cc for compaction. An additional step was the determination of the mean thickness of the water film surrounding the particles at the beginning and at the end of the test by means of the formula

$$A = \frac{W}{S_0 \Delta}, \quad (1)$$

where A is the thickness of the film of water in cm, W the moisture of soil material expressed in relative units, S₀ total surface of soil material in cm²/g, and Δ the specific weight of

water in g/cc.

Moreover, the work of swelling was calculated in relation to the unit of specific surface thus:

$$A = \frac{Pdh}{S_0 V \delta}, \quad (2)$$

where δ is the compaction of soil particles (bulk density of dry soil material) in g/cc, P compression of soil material in g, dh the absolute value of swelling in cm, and V volume of the sample in cc.

The wedging tension was

$$R = \frac{M}{(a - a_0)^n}, \quad (3)$$

The coefficient M is determined from the graph (Fig. 1) as a function of the thickness a of the film of water surrounding the soil particle and of a₀, which is the thickness of the layer of water not causing wedging tension.

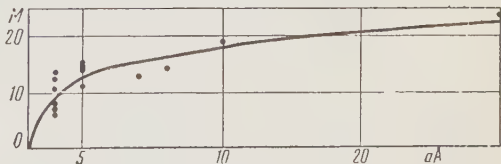


Fig. 1. - Relationship of coefficient M with a.

It is easy to see that a corresponds to the thickness of the monomolecular film of bound water (see for example Perpin (5), Dumanskii (3) and others) which is 2.8 Å, or approximately 3 Å; that is, 3 x 10⁻⁸ cm. Exponent n is 1.5 for

Table 2
Results of the investigation of swelling of soil materials at various initial moisture contents and compaction levels

Coarse clay loam				Medium clay loam 6				Coarse clay 7				Fine clay loam 10				Coarse clay				14. Medium clay, Humus, 7.6%						
3		1																								
W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε	W ₀	δ ₀	ε
3.5	1.53	5.0	8.4	1.43	7	11.1	1.40	9	11.0	1.48	14	11.7	1.41	9	9.0	1.40	14	10.5	1.28	13	10.4	1.29	15	8.7	1.32	25
"	1.64	7.0	"	1.63	14	"	1.50	12	"	1.53	16	"	—	—	"	1.49	12	"	1.37	15	"	1.35	15	"	1.44	27
"	1.73	8.0	"	1.76	11	"	1.68	10	"	1.63	17	"	1.53	9	"	1.58	17	"	—	—	"	1.48	17	"	1.49	28
"	1.84	9.0	"	1.86	10	"	1.84	8	"	—	—	"	1.60	12	"	1.70	15	"	1.44	18	"	1.47	25	"	1.57	35
6.0	1.58	2.0	9.3	1.44	8	13.7	1.47	5	"	1.82	20	"	1.71	16	"	—	—	"	1.51	19	12.3	1.29	11	11.6	1.41	32
"	1.63	3.0	"	1.55	10	"	1.54	10	"	—	—	12.2	1.44	7	16.9	1.57	5	15.2	1.27	5	"	—	—	"	1.47	30
"	—	—	"	1.68	12	"	1.69	3	"	1.96	28	"	—	—	"	1.57	6	"	1.39	7	"	1.37	14	"	1.55	33
"	1.76	4.0	"	1.85	8	"	1.75	0	"	1.98	30	"	1.56	13	"	1.70	2	"	1.43	9	"	—	—	"	1.59	35
"	1.83	4.0	16.1	1.52	1	"	1.83	0	16.0	1.48	14	"	1.67	14	19.3	1.37	5	"	1.48	10	"	1.48	15	15.2	1.31	17
"	1.87	4.0	"	1.62	1	"	1.92	1	"	1.51	14	"	1.77	16	"	1.48	5	18.0	1.27	2	14.1	1.32	10	"	1.34	16
8.4	1.54	0.5	"	1.76	1	17.1	1.46	3	"	1.69	25	19.4	1.40	3	"	1.69	6	"	1.32	4	"	1.43	14	"	1.49	22
"	1.63	0.5	"	1.87	1	"	—	—	"	1.79	26	"	1.51	4	"	—	—	"	1.54	9	20.8	1.20	10	15.5	1.36	14
"	—	—	19.1	1.46	5	"	1.58	4	19.0	1.47	8	"	1.62	5	22.3	1.44	3	20.7	1.29	0	"	1.32	13	"	1.42	16
"	1.77	2.0	"	1.63	6	"	1.73	5	"	1.68	4	"	1.67	4	"	1.50	3	"	1.39	0	"	1.39	17	"	—	—
"	1.88	2.0	"	1.69	5	24.4	1.30	3	"	1.78	3	24.3	1.39	1	"	1.58	5	"	1.42	2	"	1.58	19	"	1.48	19
"	1.93	2.0	"	1.72	3	"	1.45	3	23.0	1.37	0	"	1.49	2	"	1.65	2	"	—	—	"	—	—	"	1.52	20

Explanation: W_0 — initial moisture of soil material in % of weight; δ_0 — initial compaction of soil material (bulk density of the skeleton of soil material) in g/cc; ϵ — volumetric swelling in % of the original volume.

Note: Samples No. 11, 12, 13, and 14 have the same texture and differ only in humus content.

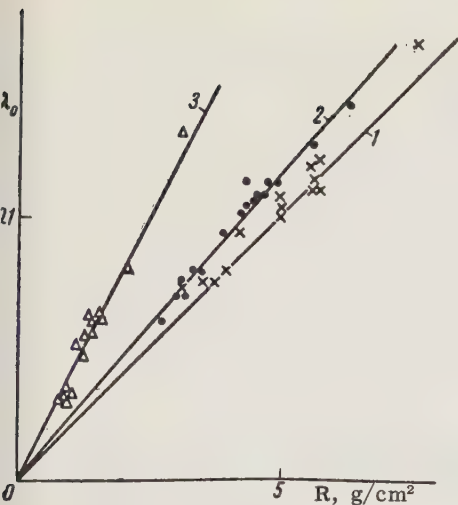


Fig. 2. - Relationship of relative swelling (λ_0) of non-compressed soil materials with wedging tension.

(R): 1 - $W = 8.5\%$; $\lambda_0 = 0.021R$;
2 - $W = 9.3\%$; $\lambda_0 = 0.021R$; 3 -
 $W = 19.1\%$; $\lambda_0 = 0.010R$.

soil materials.

Figure 2 shows the relationship of the relative amount of swelling (λ_0) with wedging tension (R) at 3 levels of initial moisture. This relationship is linear and may be expressed:

$$\lambda_0 = 0.21 WR \quad (4)$$

the value for R from formula (3) is substituted (4) we obtain the final expression for the relative amount of swelling without compression:

$$\lambda_0 = 0.21 W \frac{M}{\sqrt{(a - a_0)^3}} \quad (5)$$

is formula makes it possible to determine the relative swelling of non-compressed compacted soil materials on the basis of initial moisture content and the initial thickness of the film of water equal to a_0 .

Discussion of the Results

The following conclusions can be drawn from data in Table 2:

1. The amount of relative swelling of both humus-containing and non-humus-containing soil materials, is a function of the initial moisture content. With the increase in moisture, consequently, with the increase in thickness of the water film, just before soil material comes saturated and begins to swell, the relative swelling decreases. This may be explained

by the fact that, with the increase in the initial thickness of the water film, the number of layers of water molecules which can be adsorbed by the surface of the soil particles upon their saturation, decreases. The Deriagin effect (wedging tension) also decreases, bringing about the swelling of soil material. This assumption is confirmed by the data in Table 3, where W_0 is the initial moisture and ϵ the relative swelling in %.

2. The level of initial compaction has no bearing on the amount of relative swelling (within the limits of one moisture level). From Table 2 and formula (5) we can conclude that relative swelling is a function of levels of moisture.

3. From Table 3 it is possible to conclude that most soil materials, at an initial moisture level approximating that of the maximum molecular moisture, show the same amount of swelling.

Relative Swelling of Compressed Soil Materials

Let us consider the swelling of a thin layer of soil under uniform pressure, as a result of layers of soil above it, or constructions, etc. In this case, as investigations have shown, the absolute swelling is directly proportional to the specific surface S of soil material, to the square of soil compaction δ^2 , and to the cube of the thickness h^3 of the soil material. It is inversely proportional to the pressure P upon it and moisture W . N. N. Pavlovskiy (6) has stated that although this approach is not strictly mathematical, it is permissible if it is corroborated by experiment. According to him, the given function should also satisfy the prerequisite of equality of both members of the equation. Therefore, as a first approximation we may write:

$$\Delta h = \frac{S^x \cdot \delta^y \cdot h^z}{P^v \cdot W^u}$$

Analysis shows that in order for this to be a balanced equation, the exponents of the right side should have the following values:

$$x = 1; y = 2; z = 3; v = 1 \text{ и } u = 1$$

Thus we obtain:

$$\Delta h = \frac{S \cdot \delta^2 \cdot h^3}{P \cdot W} \quad (6)$$

Dividing both sides of (4) by h and keeping in mind that relative swelling

$$\lambda = \frac{\Delta h}{h},$$

Table 3

Mean relative swelling in % with the initial moisture content

Type of material	Sample No.	MMM	W ₀	ε	W ₀	ε	W ₀	ε	W ₀	ε
Coarse clay loam	3	8.6	3.5	7.0	6.0	4.0	8.4	1.2	16.9	0.0
Coarse clay loam	1	13.2	8.5	10.0	9.4	9.5	16.2	1.0	19.1	5.1
Medium clay loam	6	11.0	11.1	10.0	13.8	3.1	17.1	5.0	24.4	3.0
Coarse clay	7	17.3	11.0	17.0	16.0	19.8	19.0	5.0	23.0	0.5
Coarse clay	10	23.4	11.7	11.2	12.2	12.6	19.4	4.0	24.3	2.0
Coarse clay	11	16.4	9.0	14.5	16.9	4.8	19.3	5.2	22.1	1.7

we have

$$\lambda = \frac{S \cdot \delta^2 \cdot h^2}{P \cdot W} \quad (7)$$

If we designate with letter b the algebraic product of the constants for a given soil material in the right side of the equation, we obtain

$$\lambda = \frac{b}{P} \quad (8)$$

It is evident that $P = P_1 + P_0$, where P_1 is the external pressure, P_0 is the weight of the swollen layer of soil itself.

Then equation (8) becomes

$$\lambda = \frac{b}{P_1 + P_0} \quad (9)$$

By analogy with (7) we can write

$$\lambda_0 = \frac{b}{P_0} \quad \text{и} \quad P_0 = \frac{b}{\lambda_0}$$

and substituting the value of P_0 in (9) we can write

$$\lambda = \frac{b}{P_1 + \frac{b}{\lambda_0}} \quad (10)$$

Summarized data on the influence of compression on the amount of swelling are brought together in Table 4. In our experiments the following degrees of compression were used: 0.009, 0.021 and 0.081 kg/cm. In the corresponding graphs, for each soil material under the amount of compression, the increase in moisture (ΔW) is given in % in the first graph and in the second graph the amount of swelling in % of the initial volume (ϵ).

As compression increases, the amount of swelling of all soil materials decreases and becomes nil in clay loams when compression reaches 0.081 kg/cm. In experiments with clays, complete elimination of swelling was not achieved, since the highest degree of compression used in the experiments was shown to be insufficient.

The absolute increase in moisture (in comparison with the initial moisture) is nearly the same in all cases for both clay loams and clays, and it averages about 5.2%. Sample No. 3, in which the average amount of moisture increase during swelling is 10.3%, represents an exception. This may be due to the small amount of initial moisture in the material. This assumption is corroborated in Table 5.

Influence of Humus on Swelling

In our tests 4 samples of light clays with varying humus content were used. The amount of swelling at various initial moisture levels is given in Table 6.

This table reveals that in soil materials with and without humus the amount of swelling decreases with the increase in moisture, but when the amount of humus was increased, swelling also increased.

2. Both the absolute and relative rate of swelling of soil materials with humus is considerably greater than of those not containing humus. The mean amount of swelling increases in individual cases up to 33%, while the maximum mean amount of swelling in soils without humus as found in tests, does not exceed 19.8%.

3. The swelling of soil materials with humus under compression is subject to the same laws as that of soil materials without humus under the same conditions. The absolute amounts of swelling increase with the increase in humus content and surpass considerably those in soils without humus. This is shown in Table 7.

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Table 4

Relationship of the amount of swelling in % with the amount of compression

Type of material	Sample No.	Initial compression δ in g/cc	Initial moisture, W	Compression, kg/cm ²			
				0.00	0.009	0.021	0.081
Crse. clay loam	3	1.71	9.8	9	3	1	0
" " "	1	1.70	17.3	3	0.5	0.5	0
Med. clay loam	6	1.66	19.6	10	5	3	0
Clay	10	1.61	20.4	5	1	1	0.2
Coarse clay	7	1.66	23.3	0.5	0.5	0.5	0

Table 5

Mean values of moisture increase obtained as a result of investigation of swelling of compressed soil materials

Type of material	Sample No.	W_0 , %	Mean value of moisture after swelling, %	$W - W_0$	Deviation from the mean
Coarse clay loam	1	17.3	22.1	4.8	-0.4
Medium clay loam	6	19.6	24.0	4.4	-0.8
Coarse clay	7	23.3	28.2	4.9	-0.3
Coarse clay	11	19.3	25.6	6.3	+1.0
Coarse clay	10	20.4	26.0	5.4	+0.1
Clay	5	25.9	31.5	5.6	+0.3
Mean				5.27	

Table 6

Relationship of the mean relative swelling (in %) of humus-containing soil materials with the initial moisture

Sample No.	Humus content	W_0	ϵ	W_0	ϵ	W_0	ϵ	W_0	ϵ
11	0.0	9.0	14.5	16.9	4.8	19.3	5.2	22.10	1.7
12	2.2	10.5	16.2	15.3	7.7	18.0	5.0	20.8	2.1
13	4.2	10.4	18.0	12.8	14.5	14.1	12.0	20.8	14.7
14	7.6	8.7	28.7	11.6	33.0	15.2	16.3	15.5	17.2

The results of the calculation of relative swelling without compression, according to formula (5), are found in Table 8. Statistical treatment of this material gives 31% as the square deviation from the mean value of swelling in 21 tests, which may be considered wholly satisfactory in experiments with soil materials. The suggested formula allows us to calculate

the relative swelling of saturated soil materials without recourse to testing. This is very important in engineering practice where soil materials are used (dams, dikes, canals, etc.).

By means of formula (10), we can determine the amount of relative swelling of compressed soil materials (protective coating of stone or

Table 7

Moisture increase and relative swelling of humus-containing soil materials

Humus content, %	Mean initial compaction, g/cm ³	W ₀ in %	Compression, kg/cm ²							
			0.00		0.009		0.021		0.081	
			ΔW	ε	ΔW	ε	ΔW	ε	ΔW	ε
0.0	1.59	19.3	5.2	3	3.7	3	8.7	6	1.2	1
2.2	1.58	18.0	14	5	17	7	20	3	20	0.5
4.2	1.52	14.1	18	17	17	16	18	13	19	15
7.6	1.43	15.9	34	35	30	23	28	19	23	12

Table 8

Amount of swelling, calculated by means of formula (5) and determined experimentally

Type of material	Sample No.	Initial moisture W ₀	in $\frac{a}{A}$	M g/cm	λ ₀	
					Calculated	Experimental
Coarse clay loam	1	0.084	12	19.0	0.01	0.01
		0.093	13	19.5	0.01	0.09
Coarse clay loam	3	0.035	5	13.0	0.03	0.07
		0.06	8.5	16.5	0.02	0.04
		0.08	12	19.0	0.01	0.01
Medium clay loam	6	0.14	10	17.5	0.03	0.03
		0.17	13	19.5	0.02	0.05
		0.24	18	22.5	0.02	0.03
Clay	7	0.11	4	9.0	0.21	0.17
		0.19	7	15.5	0.07	0.05
Clay	11	0.09	4	9.0	0.16	0.14
		0.16	7	15.5	0.06	0.05
		0.19	8	16.0	0.05	0.05
		0.22	10	17.5	0.04	0.01
Clay	12	0.15	7	15.5	0.06	0.08
		0.18	8.5	16.5	0.05	0.05
		0.20	10	17.5	0.04	0.02
Clay	13	0.12	5	13.0	0.12	0.14
		0.14	5	13.0	0.13	0.12
	14	0.152	5	13	0.14	0.16
		0.155	5	13	0.15	0.17

concrete on the banks of irrigation canals, etc.) or solve the converse problem of what compression is to be applied to attain a certain amount of swelling.

The formulas are so simple that they do not require testing. It should be mentioned that the solution of the second problem has great significance in the practical utilization of soil as structural material in ameliorative projects. So far as we know, no such solution has been

proposed until now.

The determination of the total surface area of soil materials has been repeated 3 times, following the method of Dumanskiy. During the investigation a constant relationship between the total surface area and MMM (maximal molecular moisture), as given by A. F. Lebedev, was found. This relationship is shown in Table 9 and may be expressed empirically as:

$$S_0 = C \sqrt{MMM}^3 \quad (11)$$

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Table 9

Values of coefficient (C), calculated by means of equation (11), and total surface area (S_0) in relation with maximal molecular moisture (MMM)

MMM, %	C	S_0 , m ² /g	MMM, %	C	S_0 , m ² /g	MMM, %	C	S_0 , m ² /g	MMM, %	C	S_0 , m ² /g
1.0		7.5	7.0	2.7	49.0	13.0	2.2	105.0	19.0	3.9	381.0
2.0	5.3	15.0	8.0	2.6	59.0	14.0	2.6	118.0	20.0	4.4	397.0
3.0	3.9	21.0	9.0	2.5	68.0	15.0	2.3	126.0	21.0	5.1	491.0
4.0	3.3	27.0	10.0	2.4	76.0	16.0	2.5	161.0	—	—	—
5.0	3.0	34.0	11.0	2.3	86.0	17.0	2.8	200.0	—	—	—
6.0	2.8	41.0	12.0	2.3	95.0	18.0	3.3	255.0	—	—	—

ere C is the coefficient to be obtained in
ole 9.

Thus it is possible to calculate with satis-
tory accuracy the total surface area of
l material on the basis of the MMM deter-
nation, a task which should not be too dif-
cult even for a poorly trained laboratory
sistant.

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REGIONAL SOIL CLASSIFICATION IN THE USSR¹

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The most important task for all sciences related to agriculture is to increase the crop yield and the productivity of livestock. In order to increase crop yields it is necessary to distribute the different branches of agriculture properly; i. e. in the various zones and regions it is necessary to specialize in accordance with the natural and economic conditions, to promote crop rotations according to each climatic soil zone, and to apply a sound system to management, fertilization, and ameliorative practices. To accomplish these aims, there must be, on a physical and economical-geographical basis, a sound regional classification for agricultural purposes of the soils of the USSR. We do not intend to survey the history of the regional classification of the USSR. We mention only that the last great work along these lines was the comprehensive regional soil classification made by the special commission of the SOPS, Academy of Sciences, USSR, under the leadership of V. L. Komarov, L. I. Prasolov, S. G. Strumilin and I. S. Lupinovich. The present project of SOPS, under P. A. Letunov, with the cooperation of the V. V. Dokuchayev Soil Institute, is a direct continuation of the special commission's work. Recently, a great part of this project was also carried out by the regional commissions of the V. I. Lenin Soviet Academy of Agricultural Sciences and by the state commissions for the establishment of an agricultural management system. In 1957, on the initiative of the biological soil science faculty of Moscow State University, with the support of the Ministry for Higher Education, eighteen USSR universities undertook to continue the project of regional soil classification. At present, this work is being carried out in the following divisions: physical-geographical (including climatological, geomorphic and hydrological), soil science, economical-geographical and, partly, geobotanical and zoological. The universities have always been centers of natural

and agricultural research in their various republics, regions and districts and they have accumulated a great amount of scientific material. Under the leadership of Moscow University, some universities have led in accomplishments of great agricultural value to the Union as, for example, soil investigation and soil classification to establish a state network for crop variety tests. It is important to make available, publish, and formulate these materials, to make them of practical use. This would be a valuable contribution by the state universities and of help to socialist agriculture. It would also be of great theoretical interest because it is the sum total of our knowledge of the nature of the country, and is necessary for sound utilization of our natural resources for agriculture.

Regional soil classification is very important in general regional classification. Soil is the basis on which agricultural production is calculated, is itself a product of nature, and reflects the totality of environmental conditions. Regional soil classification, carried out soundly within the framework of natural and economic classification, would be the foundation for establishing a system of agricultural measures to increase agricultural production rapidly on 100 hectares.

The same organizational outline used in the soil investigation of test plots was adopted to carry out the complex inter-university project of regional soil classification. The USSR was divided into a number of sectors; each was assigned to a corresponding university or to an agricultural institute, and the responsibility for carrying out the project was entrusted to a person in charge of that sector. Three meetings were held for all sections of the natural and economical-geographical classification, as well as for the specialized regional soil classification. The inter-university meeting for the latter was held in May 1957, and the instructions for soil classification were discussed and confirmed. These instructions included the following points: 1) problems of

¹ Delivered at the First Delegates' Congress of Soil Scientists in May 1958.

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regional soil classification; 2) taxonomic units of soil classification; 3) scales of the cartographic maps for regional soil mapping; 4) nomenclature of soils and soil regions; 5) outline for the description of soil regions; and 6) dates for the completion of regional soil classification. Only the taxonomic units of regional soil classification contained in the foregoing will be discussed, since this is of general interest and is necessary to establish a uniform system of nomenclature in the various republics and regions.

The following are the taxonomic units used in regional soil classification: soil region (oblast), soil zone, soil subzone, soil province, soil subprovince or section (okrug), and soil district (raion).

A soil region denotes a part of the territory characterized by a certain combination of horizontal or vertical soil zones.

A soil zone is a horizontal or vertical segment of land in which a basic zonal soil group predominates.

A soil subzone is a horizontal or vertical division of a zone occupied by a certain subgroup of a zonal soil.

It may be necessary in certain cases (the zone of gray forest soils; the chernozem zone; the zone of chestnut and brown soils) to consolidate the individual subzones which are related because of their natural conditions (for example, subgroups of the gray forest soil group; all subgroups of podzolized, leached, and deep chernozems; subgroups of dark-chestnut and chestnut soils; subgroups of light-chestnut and brown soils).

A soil province is part of a soil zone which shows certain differences in structure and composition caused by various bioclimatic conditions of the individual portions of the subzone.

A soil subprovince (section) is part of a province in which a combination of soil complexes, caused by the peculiarities of relief and soil-forming parent material, predominates.

A soil district is part of a subprovince or, in individual cases, of a soil province, or, in mountainous regions, even of a soil zone or province. It is characterized by a uniform relief, parent material, and other factors of soil formation. The soil district is the basic elementary unit of regional soil classification and, at a certain stage, the mapping and description of these districts are the main task of the project.

When carrying out regional soil classification it is necessary to consider the type of

productivity influence on the conditions of soil genesis (cultivated and non-cultivated soils, drainage, irrigation, development of erosional processes, secondary water-logging, salt accumulation, crops or, conversely, exhausted soils). Depending on the degree of these factors, it is possible to establish subdistricts within the districts.

In certain cases subzones, provinces, and subprovinces may not exist.

Ten universities and six agricultural institutes now participate in the project. These are the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, and soil institutes of the academies of sciences of the Union republics. Moscow University (the department of soil geography of the faculty of biological soil science) not only leads the entire project and is responsible for the construction of the definitive map of USSR soil regions, but is also in charge of soil classification of eleven regions of the central non-chernozem sector. The department of soil geography has made a regional soil map of this sector and a general soil map of the European part of the USSR at a scale 1:1,500,000.

Leningrad University, under the leadership of A. A. Zavalishin, has mapped and described the soil regions of the north and northwest republics and regions of European USSR. Voronezh University (under P. G. Aderikhin) has done the same for the central chernozem areas. The soils of the Lower Don were mapped and described by Rostov University. The following institutions also mapped and/or described, their respective assigned regions: Saratov University (under A. F. Neganov), Saratov region; Perm Agriculture Institute (under N. Ia. Korotaev), Perm region; Bashkirian Agricultural Institute (under S. N. Taichinov), Bashkirian ASSR; Orenburg (Chkalov) Agricultural Institute (under V. D. Kucherenko), Orenburg region; Irkutsk University (under O. V. Makeev), jointly with the V. V. Dokuchayev Soil Institute, Baikal Siberia; Yakutsk branch of the Academy of Sciences (under V. G. Zol'nikov), Viliui basin; Far East Agricultural Institute (under A. I. Kachiiani), soils of the Far East; Kiev University (under N. B. Vernander), mapped the entire Ukrainian SSR; Tiflis (Tbilisi) University, together with the Academy of Sciences of Georgian SSR, (under M. N. Sabashvili), Georgian SSR; Armenian Agricultural Institute (under Kh. P. Mirimanian), Armenian SSR; Soil Institute of Azerbaydzhan SSR (under V. R. Volubuev), mapped Azerbaydzhan SSR.

This regional soil classification is carried out in contact with VASKhNIL on the basis of agricultural management. The results, in the majority of the republics and regions, are used immediately for taking measures to increase agricultural production on 100 hectares of arable land.

Moscow State University, apart from the work mentioned previously, also leads special soil expeditions in Moscow, Vladimir, Ivanov, Iaroslav, Kaluga, and other regions. Besides field trips throughout the territory for delimiting the borders of the soil regions, this work also includes a detailed investigation of soils at the key areas. The nature of the basic key areas of the plots in the state network is investigated by means of crop variety tests. The selection of the key areas was made because the University had been investigating their soils and their soil classification since 1937, by establishing experiment stations. Moreover, the experiment stations are on farms with outstanding agricultural methods and high yields, which often surpass two, or even three times the yield on the surrounding collective lands. Together with soil classification, locations are found where the varieties tested and the agricultural practices of the test plots may be established, and where the testing may be most successful in furthering agricultural development.

At present, the most important task for achieving increased yields and general improvement of agriculture is disseminating propaganda and exerting pressure to spread agricultural knowledge and advanced testing. The state experiment stations will play an important part. From the beginning the test plots were correlated with soil regions. Later, this prerequisite of correlation was unfortunately disregarded, because part of the plots were discontinued and new plots were started without regard for their regional classification. Nevertheless, a considerable number of test plots belong to specific soil regions. Wherever crop rotation, variety testing, and good agricultural practices were maintained, these plots, in their twenty years of existence, have contributed to the understanding of the various ways of

attaining high yields. This experiment can and should be extended. These test plots are recommended because adjacent collective farms can easily become acquainted with them and, thus, propaganda and indoctrination be concrete and easily comprehended. Publicity for this experiment and listing of areas where the experiment can be adopted, are part of the work of the regional soil classification of the central non-chernozem regions. Thus, the project of soil classification will achieve its aim in production.

The utilization of quality criteria of basic test plots in regional soil classification will be of great help in future important work on site quality and economic land evaluation. At a certain point in this project, the All-Union (Federal) Research Institute of Agricultural Economics will be able to make use of the accumulated statistical material on the yield of the state variety test plots. Each plot has data on the yield of standard agricultural crops and new varieties covering many years. This was obtained by means of comparable agricultural practices and was related to determined soils and soil regions. There are about 1500 variety test plots in almost all kinds of soils, evenly distributed throughout the Soviet Union.

Further progress along lines indicated by us, may be very effective in promoting a healthy development of economic land evaluation. Widespread participation in the regional soil classification project by local experts who know the soils of their respective republics and regions and who are in close contact with local agricultural organizations, will permit the quick, successful completion of this important task, which is so urgent and which also has great theoretical interest.

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DISCUSSION

AN OUTLINE OF SOIL CLASSIFICATION OF PLAIN TERRITORIES OF THE FAR EAST

YU. A. LIVEROVSKIY and L. P. RUBTSOVA

Soil classification of the Soviet Primor'e and of the Amur region remains unfinished for the present. Differences of opinion prevent sound utilization of lands and their qualitative and quantitative evaluation. For this reason, the V. V. Dokuchayev Soil Institute called an interdepartmental meeting on April 7-10, 1958, to discuss soil classification and regionalization of the areas mentioned.

The Academy of Sciences was represented at the meeting by the V. V. Dokuchayev Soil Institute, the Far Eastern Branch of the Academy of Sciences of the USSR, the SOPS, and the Geographical Institute. Other organizations taking part were: the State University of Moscow, the Far Eastern Agricultural Research Institute, the Rosgiprovdokhoz and Sojuzgiprovdokhoz of the USSR. Ministries of Agriculture and the Russian Soviet Federated Socialist Republic, and the Fourth Geological Administration.

The following persons presented papers at the meeting: 1) Yu. A. Liverovskiy, L. P. Rubtsova (V. V. Dokuchayev Soil Institute) and N. N. Firtsov (SOPS): "An outline of soil classification of the Amur region." 2) Liverovskiy and Rubtsova: "Geographical soil classification of Amur region." 3) F. I. Ivanov (DVFA): "Soils of the Kanka lake plain and of the Ussuri river valley." 4) A. I. Kachin: "Survey and agricultural evaluation of virgin lands of Primor'e." 5) N. D. Pustovoytov: "Hydro-physical conditions of soils of Amur region." 6) V. A. Kovda and B. A. Zimovets: "Geochemical classification of Amur region."

In the subsequent discussion the following took part: B. P. Kolesnikov (Ukrainian Branch, Academy of Sciences); N. A. Kachinskiy, E. N. Yanova, N. N. Rozov, N. I. Garbunov (V. V. Dokuchayev Soil Institute); B. A. Kalachov (Rosgiprovdokhoz) and others.

On the basis of the material presented and its evaluation by Liverovskiy, Neunlyov, Kachin, Ivanov, Rubtsova and Firtsov, a soil

classification of the plains of Primor'e and Amur region was outlined. After further evaluation and elaboration, this outline was accepted at the meeting and recommended for use with additional study during the soil investigations of the Far East.

In this report the adopted outline is given and certain peculiarities of the soil taxonomic units are discussed.

Soils of the Taiga Zone

The vegetation consists of the southern and central taiga open coniferous, Larix and Larix-Pinus forest, and dense coniferous Picea and Picea-Abies forest.

The soils under the taiga forest are considered a special group, the "brown taiga soils," within which several subgroups are recognized. An important characteristic of these soils is the internal weathering which causes a distinctive clay formation of the soil mass.¹ When the soils are formed on fine-textured parent-material, podzolization is either weak or not evident.

In podzolic soils the upper part of the profile (Horizon A₂) is leached of iron and aluminum. The maximum content of these elements, usually clearly indicated, is found in the central part of the profile and coincides with the alluvial zone. In brown taiga soils, the distribution of iron and aluminum (determined by Tamm's method), is similar to that of the brown forest soils, but not to that of the podzolic and sod-podzolic soils. In brown taiga soils, the iron and aluminum content reaches a maximum in the upper part of the profile and

¹Descriptions of internal weathering in soils of the Far East under central taiga are given in a paper by Yu. A. Liverovskiy. Soils of the Upper Zei region. DVK "Problems of Soviet Far East." AN. SSSR. 1931.

gradually decreases with depth; only in podzolized brown taiga soil is there an indication of a minimum of these oxides in the podzolized horizon and a weak maximum in the alluvial zone.

Brown taiga soils have a poorly differentiated morphological profile. Forest litter is usually thin, on the average about 2 to 5-6 cm thick. Under vegetation consisting of mosses and *Rhododendron dahuricum* L. the thickness of the litter layer reaches 10-12 cm. In this case it incorporates stems and roots and has a crumbly, elastic character. The humus incorporated A_1 Horizon is thin, about 7-8 cm, rarely 10-12 cm thick. Below lies Horizon AB, 13-17 cm thick. It has a grayish-cinnamon-brown coloring and is lightly compacted. In some cases Horizon AB is missing. Then the humus incorporated horizon lies directly on the horizon of metamorphism B. The latter is brown or cinnamon-brown, clayified and compacted as a result of internal soil weathering. Farther down is Horizon BC, usually of the same color but with a lower clay content.

The presence of gley is a constant characteristic of brown taiga soils. These soils differ from the brown forest soils by their higher acidity (pH in water is 5.2-6.6 in the upper part of the profile and 4.4-4.2 in the lower) and by their unsaturated bases. Analyses of the humus of brown taiga soils show a considerable predominance of fulvic acids tied with sesquioxides (ratio $\frac{\text{humic acids}}{\text{fulvic acids}} = 0.4$).

Brown taiga soils are similar to the "acid non-podzolized" or the "acid, weakly podzolized" soils from Central Ural Mountains described by E. N. Ivanova in 1947 and to those from Karelia described by V. V. Ponomareva in 1935.

Two basic subgroups are recognized. To the first subgroup belong 1) brown taiga soils and 2) brown taiga podzolized soils. The second group consists of 3) brown taiga frozen soils and 4) brown taiga frozen podzolized soils.

Brown taiga frozen soils (subgroups 3 and 4) develop under scattered coniferous forests of the central and southern taiga in the permafrost region and also in those areas where deep seasonal freezing thaws slowly.

Brown taiga soils (subgroups 1 and 2) are found in regions where permafrost is absent and thermal conditions are less severe. The degree of podzolization in both the brown taiga and brown taiga frozen soils, when it occurs, is very small. Under the humus horizon there appears a whitish layer no more than 3-4 cm thick. The podzolized layer loses only a fraction of clay and iron compounds.

Peculiar taiga soils, as yet not sufficiently investigated, are found under dense, coniferous, *Picea-Abies* forests in northern Amur region and in the high altitudes of the central Sikhote-Alin'.

The humus-illuvial processes are present in them, although the podzolization process is absent or only weakly indicated. On the basis of preliminary data, these soils are placed provisionally within a special group of the "humic-illuvial taiga soils" and "taiga humus-illuvial podzolic soils." Within the taiga zone there are large areas with special soil groups, namely brown taiga bog soils (type b) and frozen bog soils (type c). These soils need further investigation.

Soil Zones of the East Asian Coniferous-broadleaf Forest and Prairie

Brown forest soils are the zonal group and occupy the mountainous regions and the plains in the Far East.

The brown forest soils of Amur region have all the essential characteristics of similar soils of Western Europe, Crimea and Caucasus. These characteristics are: 1) accumulation of humus with a high content in ulmic acids; 2) the stability of clay minerals formed as a result of internal weathering; 3) the absence, or at most a weak indication, of podzolization and the stability of iron compounds.

But, together with the general group characteristics, certain facies and provincial peculiarities appear in brown forest soils of Amur. Because of the monsoon type of climate, these soils can form only where drainage is very good and soil aeration takes place. These conditions are fulfilled in stony soils of the mountain slopes and in similar situations on coarse-textured parent-material, sands and sandy loams. Although the brown forest soils in Amur region arise from coarse-textured parent-material of varied mineralogical composition and origin, the process of their formation is always accompanied by an intensive clay formation. Therefore, even when brown forest soils are formed on tertiary sands, these become covered by a layer of clay loam eluvium to a depth of 80-100 cm. The formation of eluvium is due to internal weathering. This is avoided, under the conditions of the southern Amur region, only on very acid soil parent material, poor in feldspars and rich in quartz.

Brown forest soils of Amur region exhibit the following profile. Under Horizon A_0 , which consists of forest litter slightly turned into peat and only 2-3 cm thick, lies the humus horizon, cinnamon-brown-gray or brownish-gray in color and 6-8 cm thick. In podzolized brown forest soils the humus layer A_1 lies on a poorly

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developed A₂ Horizon, which is whitish or yellowish-whitish in color; its thickness is 5-7 cm. Horizon B has a reddish-brown or dark-brown coloration; it has a clay formation and is compacted.

The humus content in brown forest soils is high (8%-12%), but it decreases rapidly with depth. Thus humus contents are not large. In the organic material, the content of brown ulmic acids is high.

A special trait of the brown forest soils of the Amur region is the high percentage base saturation. The actual reaction of the soil is weakly acid, the pH varies from 5.8-6.5. In this group, the subgroup of brown forest podzolized soils is recognized. The morphological signs of podzolization are not distinct. The podzolized A₂ horizon has a thickness of 5-7 cm, often only 4-6 cm. The total thickness of Horizons B and C combined is 50-60 cm. The poor development of podzolization is confirmed by both particle-size and chemical analyses (somewhat lower clay content in the A₂ Horizon and the uniformity in acidic content throughout the entire profile). Total chemical analysis of the clay fraction of the various horizons of podzolized soils is uniform.

The identification of brown forest soils in the Amur region is of great practical significance. These soils are of great interest in agriculture, since in certain areas they represent great expanses of natural arable land.

Owing to an excellent drainage (from closely underlying sand), the negative consequences of temporary excessive moisture are manifested to a lesser degree on such soils, than on fine-textured meadow soils. Together with this, there are also some characteristics that are unfavorable from the agricultural viewpoint, namely 1) rapid soil exhaustion; 2) the possibility of erosion development, especially in the brown soils of elevated, broken-up plains.

As previously mentioned, in the Far East region the process of brown forest soil formation takes place only when drainage is good. Even a small reduction in drainage brings about the formation of gley layers in these soils. Usually such phenomena are correlated with a decreased infiltration capacity of the soil as it becomes finer in texture, or because of the more deeply located draining layer of sand underlying the clay loam eluvium. Gley formation, therefore, is not associated with high ground-water level but with atmospheric precipitation.

Brown forest soils (group A, subgroups 1 and 4) cover large areas of the plains between the Zey and Amur Rivers and other plains of similar origin. These plains repose on a layer of tertiary sands of great thickness overlain by

a thin mantle of loamy eluvium. The brown forest soils are formed here under pine or oak-pine forests. In these soils, generally, even when drainage is slightly reduced, brown forest, superficially gleyed soils develop.

In other cases, when the soils are formed on a clay loam or river clay or lake alluvium deposited in the early stages of the tertiary plain, and when the sandy base is located very deeply, the anaerobic conditions become more prevalent. Then, as a result of atmospheric precipitation and, sometimes, of superficial flooding by surface water, brown forest gley soils are formed which are considered as a special group (B). Sometimes they do not show indications of podzolization (subgroup 1), but often they are podzolized, if only to a small degree (subgroup 2). Analogous to the brown forest gley soils (group B) are the brown earth pseudogley of Western Europe.

In special cases soils are formed which combine the characteristics of the brown earth with those of the meadow process. These soils which attain their greatest distribution on terraces, acquire a forest cover gradually. The permanence of the meadow-herbaceous vegetation is due to the monsoon type of climate and also to the seasonal appearance of deep freezing. In the soil classification these soils are considered as a special subgroup (subgroup 3), the brown forest residual meadow soils of the group of brown forest soils (group A).

Among the indications of meadow process in these soils are the greater thickness of the humus layer and a higher humus content. Generally these soils also show a distinct alluvial texture and contain frequently, at a shallow depth, buried alluvial soils, gley layers, etc.

Within the Eastern Asiatic subzone of coniferous-broadleaf forests large areas of the group of brown forest soils are occupied by a special subgroup, the brown podzolized (brown deeply podzolized) soils (subgroup 5).

The genetic position of these soils was not clear when the systematic outline was being drawn up. As our investigations in 1958 have shown, the morphology and also many of the physical and chemical properties of these soils, covered at present by forest, are due to a previous meadow (meadow-gley) stage of development. This is confirmed by the fact that "brown podzolized" soils develop exclusively on past river or lake terraces (only sometimes covered by deluvial deposits), consisting of fine-textured alluvial clays. When drainage improves, for example, by erosion of the terraces, the "brown podzolized" soils are succeeded by the ordinary brown forest soils. The brown podzolized are distinguished by the development of a sod-humus horizon, 10-15 cm thick, that is distinctly succeeded by a whitish (A₂) horizon containing a

great number of small iron-manganese concretions (ortstein). The thickness of this horizon reaches up to 25 cm. Below the whitish layer is the variegated A_2 -B horizon, nuciform-prismatic in structure with an abundant siliceous grain sprinkling on the faces of the structural units. Very often there are clear indications of gley formation in the A_2 B and B horizons of the brown podzolized soils. These soils have a weakly acid reaction (pH 5.0-6.8) throughout the entire profile. The content in exchange bases is rather high and the content in exchangeable acids, associated with active aluminum, is considerable. Thus the "brown podzolized" soils have passed through the meadow stage, and therefore should be classified as a special subgroup. The genesis of the "brown podzolized" soils should be investigated further.

Meadow Soils

Meadow soils, widely distributed throughout the Soviet and Chinese Amur region, are represented by several groups and subgroups.

These soils are found on extensive alluvial plains and are formed on level terraces of different age and origin under meadow or meadow-steppe type. Until recently many of the meadow soils in the Soviet Amur region were considered to be sod-podzolized soils. In northeastern China the most widely distributed subgroups of meadow soils were considered to be podzolized or leached chernozems or gray forest soils.

In our list the meadow soils fall into three special groups: meadow-sod, meadow, and meadow-gley soils. In the last group the meadow process is not due to ground water. The peculiarities of its formation require special study. The meadow process of soil formation in meadow-sod soils is influenced by the water content of the soil profile, which is in many cases associated with a deep and slowly thawing seasonal frost, of no less hydrological importance than permafrost in the regions where it occurs.

Seasonal freezing changes soil water into solid phase which thus becomes stabilized within the soil. During slow thawing, the frozen horizon feeds the capillary fringe constantly and thus insures a constant water regime. Seasonal freezing either prevents, or at least slows down, the movement (lateral or gravitational) of soil water. At the same time it blocks the products of weathering and of soil formation in soil solutions considerably.

As a result of capillary transfer of solutions toward soil surface, a process characteristic of meadow soils takes place within the soil, namely hydric accumulation of silicate gels, hydroxides or iron, aluminum, allophane-like

products, etc.

Excessive soil surface moisture is also due to the monsoon climate, under which maximum precipitation occurs during the growing season. This precipitation is in the form of downpours. The second factor causing excessive surface moisture is the fine-texture of these soils and their poor water permeability.

In southern parts of the Soviet Amur region, and especially in many areas of the Chinese Amur region, where seasonal freezing ceases abruptly, the summer maximum of precipitation exerts the deciding influence on the character of soil formation.

In group (B) of meadow-sod soils two special subgroups are recognized: the meadow-sod soils proper (subgroup 1) and the meadow-chnozem-like soils (subgroup 2). As will become apparent in subsequent discussion, the latest investigations indicate the need for the recognition of an independent group, that of meadow-gley soils.²

Meadow-sod soils develop under the following types of vegetation: meadow, meadow-shrub, and meadow-forest on alluvial-lake plains located on elevated terraces. They show the following morphological features: humus Horizon A_1 is brownish-gray, 10-15 cm on the average, rarely 20 cm in thickness. Horizon B is grayish-brown with bluish streaks and with a siliceous grain sprinkling on the faces of the structural units; it consists of a slightly permeable clay. Throughout the soil profile a large quantity of small ortstein granules is apparent; their greatest number is found in the upper part of the profile.

Humus content in meadow-sod soils is not more than 5%, and it decreases very rapidly with depth; the reaction is slightly acid (pH 5.6-5.8) and base saturation rather high. In some cases, under open grass forests, weak signs of podzolization indicated by a thin whitish layer (A_2) appear in these soils. Chemical and particle-size analyses also indicate a weak podzolization.

The second subgroup of meadow-chnozem-like soils (subgroup 2) is considerably more extended. They occupy large areas within the Soviet Amur region (the Zei-Burein plain). They are even more widely distributed in the Chinese Amur region in the basins of the Nonni and Sungari Rivers. Meadow-chnozem-like soils are analogous to the chernozem-like-prairie soils of Canada and the USA.

Meadow-chnozem-like soils develop under

²These soils belong to a group called "beidzhan-tu" by Chinese soil scientists (translated as - white clay).

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meadow or meadow-steppe type of vegetation are characterized by a thick humus horizon, the average not less than 20-30 cm thick (A₁ + AB). In the deep soils of the Zei-Burein and in northeastern China the thickness of humus horizon reaches 50-80 cm, and sometimes more than 1 m. Horizon B has an even brown coloration, often with clear indications of gleying and a typical siliceous grain sprinkling on the faces of the structural units. Formation of this sprinkling is due to hydric accumulation.³

Siliceous grain sprinkling reaches its maximum at a depth of 100-120 cm. Also of hydric origin are the many, small ferro-manganic concretions. They are most numerous at a depth of 10-20 cm.

Humus of the meadow-chnozem-like soils is distinguished by its "chnozem" nature.

The ratio $\frac{\text{humic acids}}{\text{fulvic acids}}$ is 2.0 or more. In the composition of humic materials, fractions of silicic acids bound to calcium, predominate. Humus content varies from 5% to 9% or 10%. The average amount of it reaches 100 metric tons per ha or even more. The acidity of these soils is weak (pH 5.5-6.8) and base saturation is low (97%-99%). They show a high adsorption capacity (in the upper part of the profile it is 17 meq). A total chemical analysis of the entire soil and of the clay fraction indicates the absence of transfer of oxides and their uniform distribution throughout the entire profile.

These soils, because of their potential productivity, are the best arable lands of the Soviet Chinese Amur region, since they give high yields of grain and other agricultural crops. Among their objectionable characteristics are the texture and the occurrence of seasonal water causing temporary excessive moisture.

An independent soil genus within the subgroup meadow-chnozem-like soils are the meadow-chnozem-like solodized (genus b) and residual solodized soils (genus c).

The profile of the meadow-chnozem-like residual solodized soils may be described thus. The thickness of the uniformly colored humus horizon (A₁) is not more than 20 cm. This horizon is sharply differentiated from the whitish (almost white) A₂ Horizon. Below lies the dark brown, prismatic-nuciform B Horizon with siliceous grain sprinkling on the faces of the structural units. Horizon B is succeeded by a loam, alluvial fine clay; only in rare cases is there a sand layer at a depth of 1-1.5 m under

Horizon B. It should be mentioned that such a profile is not found in the residual solodized soils of other parts of the USSR (for example, Western Siberia). Usually residual solodized soils lack a distinct whitish horizon. As a result of the development of solodized soils into sod-podzolized or various steppe soils, an accumulation of humus arises within the whitish solodized layer which changes its color to gray or dark gray.

The reasons are not clear why the bright whitish layer is preserved in residual solodized soils of the Amur region. Two possible explanations follow: 1) During the process of meadow solodized soil development, solodization gives place to a special alternate-gley process; 2) within the soils of the Amur region, classified as "residual solodized," there is always some intermittent solodization.

The solution of this problem will be possible only after local observations of the dynamics of soil formation.

Humus content of meadow-chnozem-like solodized and residual solodized soils varies between 4%-5%. In Horizon A₂ it decreases sharply to 0.7% and in Horizon B it increases again to 1.5%. Group analysis of the fractional composition shows a predominance of humic acids. The ratio $\frac{\text{humic acids}}{\text{fulvic acids}}$ is about 1.5 at 0-20 cm and 1.4 at 20-30 cm. The reaction is weakly acid in upper horizons (pH 5.8-6.0). In lower horizons it is at times alkaline (pH 7.0-8.0). Total exchangeable base content is high while the exchangeable H content is insignificant. At the same time the exchangeable Na content is high (up to 3%-5% in residual solodized soils and up to 10%-15% in solodized soils).

A total chemical analysis of these soils shows a high content in silicic acid in Horizon A₂ and in sesquioxides in Horizon B, although the clay fraction scarcely varies throughout the entire soil profile.

The group of meadow soils proper, in which the subgroups of meadow soils (subgroup 1) and meadow-bog soils (subgroup 2) are distinguished, differs from meadow-sod soils formed under the conditions of seasonal freezing because they are within the reach of a constant capillary fringe of ground water. Meadow-bog soils are very widely distributed in the Soviet Amur region. The subgroup of typical meadow soils occupies limited areas in the valleys of small rivers. Meadow-solonchak, solonetz and calcareous soils are generally found in the Chinese Amur region. The already mentioned meadow-podzolized soils are insufficiently known at present.

Meadow-bog soils (subgroup 2) are of interest

A. Kovda, B.A. Zimovets, and A.G. Amchinskaya. 1958. Hydric accumulation of silica and sesquioxides in the Amur region soils. Pochvovedenie, No. 5.

as potential agricultural land, but they also have not been sufficiently investigated until now. Perhaps later they will be considered as a special group; the same is true of bog soils.

Our additional investigations, mentioned previously, have shown the necessity to separate the group of meadow-gley soils from meadow soils. These soils (known as Beidzhan soils), because of the external similarity of morphological characteristics, have been considered until now as sod-podzolized soils, and extensive areas of the southern Soviet Far East have been included into the sod-podzol zone.

Typical meadow-gley soils develop where there is insufficient transfer of minerals from ground waters which freeze every year. These soils have a definite geographical area. They are found on alluvial plains of the western slopes of Sikhote-Alin and in the intermontane valleys of the eastern Manchurian mountain region. Their main area of distribution has been determined by us as being approximately from the settlement Viatskoe (48.5° north latitude) in the north to the volcanic upland Chan-Bo-Shan (40° north latitude) in the south. Westward, as the continental climate becomes more pronounced, these soils disappear completely. They are replaced within the Soviet Amur region (Ankhara and Zei-Burein lowlands) and in northeastern China (basins of Honni and Sungari Rivers) by various meadow-sod and meadow-chernozem-like soils. Thus the meadow process is a soil forming process, associated with bioclimatic conditions characteristic of a certain sector of the Far Eastern monsoon region.

The second peculiarity of the meadow-gley soils is that they develop exclusively on lake and river terraces. They are not found in other geomorphic situations. Despite the various ages of these terraces (within the quaternary period), the deposits laid upon them are generally very fine-textured. The lake clays are of particularly wide distribution; they were deposited during the quaternary "lake period" when "lake basins" were very much in evidence throughout what today is known as the Amur region.⁴

The fine texture of the ancient lake and river alluvium is not due only to the conditions of its deposition. Apparently, during the formation of fine-textured soils of considerable areas of quaternary origin, the weathering of mountain rocks was accompanied by an intensive formation of clay products.

Meadow-gley soils have a strongly differen-

tiated profile. Humus Horizon A_1 is dark gray structured, about 20 cm thick. It changes suddenly into a mealy-whitish layer 25-30 cm thick. This layer has been considered in the past as a podzolized A_2 Horizon because of certain morphological characteristics. But it shows a number of peculiar non-pedzol traits rather indicative of meadow-gley process. Therefore it may be designated with the symbol A_g .

This horizon contains a great quantity of ferruginous and ferruginous-manganic granules. Below it is replaced by a transitional horizon (BC_g) of variegated coloration. On the generally light brown colored background of this horizon (BC_g), light streaks of siliceous grain sprinklings can be seen. It has a prismatic-nuciform structure and represents the first stage of transformation of the parent-material by the characteristic meadow process. Under this horizon lies the parent-material represented by compact dark brown clays showing a specific alluvial texture and often containing lenses of sapropel and buried alluvial soils.

The formation of typical meadow-gley soils occurs under conditions of intermittent soil surface wetting. During prolonged wetting, certain reducing processes begin within the upper part of the profile. But because of very poor permeability of the fine-textured parent-material (alluvial clays) and because of heavy seasonal freezing in certain areas, the products of soil formation are moved slowly. Only later, after the more friable, humic, and whitish gley horizons have formed, a certain amount of soil formation products begin to be removed because of lateral filtration. This is limited because of the level relief.

In the drying period of excessively wet soil made friable by roots, oxidation processes occur in the wet layer. As a result, a strong cementation of iron and manganese compounds into thin ortstein and powdery microlenses takes place in this zone of intensive aeration. These small iron and manganese formations are due to the activity of iron bacteria. The sites of these concretions within the soil coincide with the largest colonies of these bacteria.

As a result of the slow movement of the products of soil formation and of their fixation within the soil, the "Beidzhan" Horizon contains a sufficient quantity of elements required for plant growth. This brings about the development of the sod process and the formation of a relatively thick humus layer. The abundance of elements is also due to the richness of the soil parent-material of the alluvial-lake deposits.

⁴Yu. A. Liverovskiy and B.P. Kolesnikov. The nature of the southern Soviet Far East. *Geografiz*, 1947.

⁵V.A. Kovda, N.G. Zyrin, and E. Korniblum. 1958. Preliminary report on the results of investigation of mineral composition of the clay fraction of some soils of the Amur region.

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Table 1

soil classification outline of various territories of Primor'e and the Amur region (project)^a

Groups	Subgroups	Genera
I. Soils of the Taiga Zone		
Brown taiga	1. Brown taiga 2. Brown taiga podzolized 3. Brown taiga frozen 4. Brown taiga frozen podzolized	
Brown bog taiga Bog frozen Taiga alluvial-humic	1. Taiga alluvial-humic 2. Taiga alluvial-humic podzolized	
II. Soil Zones of Coniferous-Broadleaf and Broadleaf Forests and Prairies		
Brown forest	1. Brown forest 2. Brown forest surface gley 3. Brown forest residual meadow 4. Brown forest podzolized 5. Brown podzols (deeply podzolized)	
Brown forest-gley	1. Brown forest-gley 2. Brown forest-gley podzolized	
Meadow sod	1. Meadow sod 2. Meadow chernozem-like	a) Podzolized b) Solodized a) Meadow chernozem-like b) Meadow chernozem-like solodized c) Meadow chernozem-like residual solodized
Meadow	1. Meadow 2. Meadow-bog	a) Solonchak b) Solonetz c) Calcareous d) Typical (meadow proper) e) Solodized a) Humic b) Peaty
Meadow-gley Bog (lowlands) Meadow solonchaks Floodplain Floodplain bog	1. Floodplain meadow 2. Floodplain forest	

Compiled by Ye. A. Liverovskiy, B. A. Neunylov, A. I. Kachiani, G. I. Ivanov, L. P. Rubtsova
A. N. Firtsov. E. N. Ivanova, N. N. Rozov and B. P. Kolesnikov participated in the review

chemical properties of these soils are:
 us content attains 14% (sod), but usually
 es between 5%-7%. With depth humus con-
 falls rapidly to 0.6%-1.0%. The reaction is
 tly acid (pH 5.0-6.0). Base saturation is
 (90%-98%). This saturation decreases in
 zon A_g because of a high content in exchange-

able aluminum.

Total chemical analyses of meadow-gley
 soils indicate a certain movement of sesqui-
 oxides and some accumulation of silica in the
 whitish horizon. But the total chemical com-
 position of the clay fraction varies very little

throughout the profile.

These soils, as agricultural experiments in China indicate, are best suited for rice plantations. When ameliorative practices to combat soil surface moisture are adopted, these soils can be used to grow grain crops requiring drier conditions.

In the systematic list of soils, only one group of lowland bog soils is given. But in northern Amur region there are extensive areas covered by oligotrophic bogs (*Sphagnum* bogs). Therefore, it seems that the list should contain soils of river-surface bogs and temporary transitional bogs.

In the group of floodplain soils two subgroups are recognized, namely floodplain meadow and floodplain forest soils. These soils are characterized by their special soil-forming process. The group of floodplain swamp soils (I) has also been recognized. Floodplain soils of the Amur region have been investigated very little. At present, because of the monsoon hydrological conditions (high summer precipitation), the utilization of floodplain meadow soils for agricultural purposes is highly restricted. But if the flow of the Amur and Zei Rivers is regulated, there is a possibility that enormous expanses of fertile floodplain soils may be utilized. Thus investigation and further elaboration of classification of floodplain soils are the next tasks.

SOIL SYSTEMATICS OF THE KUBAN' RIVER DELTA¹

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Differences in age of the individual sections of the lower reaches of the Kuban River in respect of vegetation and other conditions influencing soil formation, bring about a great variation in soils of the area under consideration. It is possible to encounter here the entire scale of soil formations, beginning with very youthful forms and ending with fully mature soils peculiar to Kuban steppes.

Historical-geological data from previous publications (1) permit us to assume that in the regions bordering on the flood plains and the delta of the Kuban River, the process of soil formation began earlier than in other surrounding areas. Therefore, the soils of these areas are the most advanced. At present bioclimatic factors play an important role in their development. Ground waters are comparatively deep (5-12 m or more), and biochemical processes develop normally under the existing conditions of atmospheric precipitation. The diversity of climate and vegetation in bordering areas has caused development of three basic soil groups: chernozems, gray forest soils, and the special chestnut soils.

Steppe-meadow soils represent a younger group occupying the area of the former delta and the more elevated and rarely flooded section around the lower Kuban River. On the basis of vegetation these areas are meadows that have become, or are becoming, steppes.

The soils of this group, like those of the preceding groups, develop chiefly under the influence of atmospheric precipitation, and are affected by ground waters, and sometimes by high flood waters. These soils, which maintain weak indications of bog (rust stains, concretions, etc.) in lower horizons showing their alluvial origin, resemble chernozems in general aspects. On the basis of the degree to which chernozem characteristics are ex-

pressed, they are divided into chernozem-like meadow and chernozem-meadow soils.

Hydromorphic soils are a special group. In their development the influence of zonal factors is obscured by the effects of high or even excessive wetting (by ground and flood waters) and partly by periodically deposited alluvium.² Bog, bog-meadow and meadow soils belong here. They are younger than chernozem-meadow soils.

Equally young is the group of alluvial soils that have been affected very little by the soil formation process. Saline and solonetz-like soils are rather widely distributed in the lowlands of Kuban River. In certain places solonetz soils are also found. Considering the genetic characteristics and the evolutionary relationships of the Kuban delta soils and those of adjacent areas, it is possible to classify them in the following way.

I. Alluvial deposits affected little by the soil formation process (bog-meadow and meadow): 1) littoral, 2) delta-estuarine: a) non-saline, b) partly solonchak, c) solonchak-like, d) fluvial-alluvial.

II. Bog soils (marsh): 1) peaty, 2) peaty-gley, 3) humic-gley: a) typical (non-saline), b) partly solonchak, c) solonchak-like, 4) bog-meadow: a) typical (non-saline), b) partly solonchak, c) solonchak.

III. Meadow soils (flood plain soils): 1)

²From what has been said it does not follow that development of flood plain-delta soils of Kuban River is not secondarily influenced by zonal conditions. In one of the first stages (bog stage) of their development, this influence becomes evident by the fact that the bog process is accompanied by peat accumulation; whereas in dry, desert regions there is almost no accumulation of peat in flood plains and deltas. As vegetation develops, the zonal factors become less and less decisive.

alluvial-meadow, 2) meadow: a) typical (marsh-like), b) partly solonchak, c) solonchak-like, d) partly solonetz-partly solonchak, e) solonetz, 3) forest-meadow.

IV. Steppe-meadow soils: 1) chernozem-like meadow: a) typical (non-saline), b) partly solonchak, c) partly solonetz-partly solonchak, d) solonetz, 2) chernozem meadow: a) calcareous, b) slightly leached (typical), c) leached, d) leached, slightly compact, e) slightly solodized, sometimes solodized.

V. Chernozems: 1) calcareous, little humic, very deep (western-ciscaucasian), 2) typical, little humic, very deep (somewhat leached western ciscaucasian), 3) leached, little humic, very deep, 4) leached compacted, 5) partly solonetz, medium deep and deep, 6) little humic, transitional to chestnut soils.

VI. Chestnut soils: 1) calcareous, deep, 2) solonetz, shallow.

VII. Dark gray and gray forest soils.

VIII. Solonchaks: 1) littoral, sulfate-chloride soils, 2) meadow-bog (marsh), predominantly sulfate-chloride soils, 3) meadow, sulfate-chloride and chloride-sulfate soils.

IX. Solonetz soils: 1) solonetz-solonchak meadow soils, nuciform and blocky: a) sodium salts, b) sulfate-chloride, c) chloride-sulfate, 2) solonetz meadow, blocky and columnar (encrusted and average): a) sulfate-chloride, b) chloride-sulfate, c) sulfate-sodium, d) sulfate-sodium salts, 3) solonetz meadow-steppes, medium-columnar, predominantly chloride-sulfate, 4) solonetz steppe soils, blocky and columnar (encrusted and average), predominantly chloride-sulfate).

In the preceding systematic list the following taxonomic categories are given: soil groups (I, II, III, etc.), subgroups (1, 2, 3, etc.), species (a, b, c, etc.). These categories were accepted in the sense of Prasolov (8, 9) and since then perfected by Gerasimov (3, 4) and Ivanova (5, 6). Within a soil species varieties may be recognized on the basis of texture. Varieties were not included in the foregoing list.

To separate soils according to the degree of salinity, the following standards of salt content within the upper 1 m layer were adopted: non-saline soils, less than 0.3%; partly solonchak soils, 0.3%-0.5%;³ solonchak-like soils, 0.5%-1%; solonchaks, more than 1%.

In separating chernozems on the basis of thickness, the following criteria were used: chernozems having a thickness of Horizons A + B greater than 120 cm were considered very deep; where the thickness of A + B horizons was 80-120 cm they were considered deep; when A + B thickness was 50-80 cm they were called medium deep; and when A + B thickness was less than 50 cm they were called shallow.⁴

On the basis of humus content, chernozems were divided into poor in humus when humus content in the plowed horizon was less than 4%, little humic when the content varied between 4%-6%, and medium humic when the content was 6%-9%.

The nomenclature adopted by the V. V. Dokuchayev Institute, Academy of Sciences of the USSR and confirmed by the 1950 All-Union Congress for soil cartography and nomenclature was used in naming the soils. For this reason some new names have been substituted. For example, these terms have been introduced: 1) "humic-gley soils" instead of "marsh-bog," 2) "meadow-chernozems" for "sod delta soils," "valley chernozems," 3) "calcareous, little humic, very deep chernozems" instead of "western ciscaucasian calcareous chernozems," etc. In the case of chernozems, together with the new names, the old ones are given in parentheses in order to maintain continuity.

Certain diagnostic traits of the basic groups and subgroups of the flooded delta soil of Kuban River are given below.

I. Deposits affected little by the process of soil formation. They are found on littoral river bottoms of recently dried out deltas or river estuaries, elevated river banks of the Kuban River and its affluents. They may be considered as young soils from which other, more developed soils originate.

Their vegetation is sparse. Profile differentiation and genetic horizons are almost absent. Only the surface, humic-accumulative horizon, of no more than 10 cm in thickness can barely be distinguished. Its humus content is no more than 1.7%. In fluvial deposits vertical stratification is characteristically distinct. The process of soil formation in littoral and fluvial deposits is very similar to that of the meadow type; in delta-estuarine deposits it is mainly of the bog-meadow type.

II. Bog soils (marsh). They are found mostly in the marshy parts of the delta, which undergo a prolonged flooding by river waters. The degree of gleying, and peat and humus

³ When salt concentration below 1 m is more than 0.3%, then such soils are also considered as partly shallow.

⁴ This scale was also used in dividing the chestnut soils into deep and shallow.

development is used as a criterion for their division into subgroups.

Peaty soils (marshy peats) have a 50 cm 1.5-2 m thick layer of peat on their surface. In most cases this is coarse, undecomposed partly decomposed, of the reed type, often with mineral admixtures. Ash content is high, 30%-40%, sometimes about 70%, and pH varies from 5.7-6.7 throughout the profile. In lower horizons, those bordering on gley, the reaction may be very acid (pH 4.7).

Peaty-gley soils differ from the foregoing by their thinner peat layer (15-50 cm). Moreover, a slightly humic layer is found in them between the peat and the gley horizon. This humic layer is always missing in peaty soils. Ash content of the peat layer is 30%-60%. The reaction, both in the peat layer and the lower layers, is mostly weakly acid (pH 5.8-6.6). Varieties of this group, mixed with recent alluvium, have a weakly basic reaction.

Humic-gley soils are characterized by the absence of the surface peat layer. An upper humic horizon (A), 10-40 cm thick, and a lower one, the gley horizon (G) which gradually merges with parent material, may be easily recognized in these soils. Humus content in the upper horizon is 5%-13% sometimes 15%. In the gley horizon it is 2.5%-1%. Total humus content in the upper 50 cm is on the average 285 metric tons per ha. Total nitrogen content in the upper horizon is considerable (0.3%-1%). The C:N ratio is about 9-10 and at greater depths it widens to 14-16. In soils that have been submerged under water for considerable time this ratio becomes 12-13 in the upper horizon.

The absence of carbonates in the upper layers is characteristic of humic-gley soils. General effervescence from acid is observed only at depth greater than 100 cm. Adsorption capacity is high: in humic horizons 53-67 meq; in the lower gley horizons 45.5-50.5 meq. Among saturated cations Calcium (79%-90%) predominates in the exchange capacity. The pH of the upper layers is 6.5-6.7 and increases with depth to 7.3.

Total porosity (62%-79%), field moisture capacity (48%-67%), and maximal hygroscopicity (39%-19%) are also very high in the upper layers of these soils. This may be explained by their fine-texture in the upper profiles and also by the high organic content.

Bog-meadow soils develop under conditions less water than is the case for humic-gley soils. As a result the profile does not show the effects of water-logging as clearly as humic-gley soils. Their gley horizon is located at a greater depth. Rusty iron veins, indicating oxidation, are found in great numbers, not only

in the lower depths of the humus horizon, but even in the gley horizon. The humus horizon is somewhat thicker (30-40 cm, sometimes 60-70 cm). In the upper layers, the humus content is 7%-8% and varies between 3%-17%. Such a wide variation is caused chiefly by variations in vegetation and also by the different ages of these soils.

Total humus content within the first 50 cm averages 270 metric tons per ha. Thus, in comparison with humic-gley soils, there is no greater humus accumulation in these soils in the upper 50 cm. This is probably due to the attenuation of the anaerobic process in this part of their profile and to a more intensive decomposition of the plant residues. Total nitrogen content is 0.22%-0.44% in the upper horizons; C:N ratio is 8-10.

III. Meadow soils (flood plain). They develop in situations more elevated than bog-meadow soils; i. e., under conditions of less moisture. Therefore, in comparison with the bog group, a weakening of reduction and an intensification of the oxidation process is noticeable in their profile. This is indicated by the fact that the gley horizon is altogether absent or appears only as discontinuous bluish mottling. Rusty-brown mottling, due to iron, is found more often and reaches to a greater depth than in bog soils. In order to divide the group of meadow soils into subgroups, account was taken of the degree to which the sod and alluvial process was indicated, of vegetation, and other conditions of their development.

Alluvial-meadow soils were formed where the alluvial process was fairly intensive; the significance is expressed in their name.⁵ Parent material is layered (multi-phased) alluvium. They are genetically related to fluvial-alluvial deposits, and as a result preserve within their structure and properties many characteristics of the latter. Their profile is poorly differentiated. The thickness of the humus horizon is 27-30 cm, on the average. Highly characteristic is the presence of buried humic layers in the profile. Because of their young age, these soils have been affected little by leaching. Effervescence can be observed at shallow depths, usually at the lower margin of the humus horizon.

Humus content is 3%-5% in the upper horizon. Total humus content within the upper 50 cm varies from 88 to 154 metric tons per ha, i. e., it is considerably lower than in humic-gley and bog-meadow soils. This may be explained by the fact that vegetation on these soils

⁵ According to V.R. Vil'yams these are the so-called "platy soils." Other authors describe them under the name of "accumulative-sod-platy" (7), "sod-platy" or "granular-platy" (10).

is less dense and also by their location in situations of a more intensive aeration. The total nitrogen content is 0.18%-0.28% in the upper horizon. C:N ratio does not exceed 11. Because of little leaching, pH is relatively constant throughout the entire profile (7.4-7.7). Adsorption capacity for the fine clay loams is about 40 meq; for the clay loams 31-33 meq.

Meadow soils, as compared to alluvial-meadow soils, develop under conditions of a more active biological (sod) process, but with a slight alluvial process.⁶ They are genetically related to bog-meadow soils. They develop on alluvium, which is uniform in texture, and thus lack in their profile the sequence of layers characteristic of alluvial-meadow soils. Among their other characteristics are: a fairly considerable thickness of humus horizons (A + B is 70 cm, with a range of 40-100 cm), a distinct crumbly or crumbly-granular structure in the upper part of the humus horizon, and considerable leaching of carbonates (effervescence usually takes place in C Horizon).

Humus content in the upper horizon of meadow soils is 4.5%-7.5%. Total humus content of the upper 50 cm is about 318 metric tons per ha, i.e., they are richer in humus than alluvial-meadow soils. The reaction in upper layers is nearly the same as in middle layers (pH 6.3-6.8) and below, because of carbonate accumulation, it becomes slightly basic (pH 7.3-7.9). Adsorption capacity is somewhat higher than in alluvial-meadow soils: in A Horizon it is 35.8-52.3 meq, and in B Horizon it is 31-42 meq.

Forest-meadow soils are found in elevated parts of the flood plain of Kuban River and its affluents. As a rule, they are covered by forest or shrubs. The influence of forest is indicated by a certain decrease in humus in the upper horizon and by the appearance of a gray coloration and a nuciform structure. Horizon A is 15-30 cm thick, A + B is 47-60 cm.

IV. Steppe-meadow soils. Two subgroups, the chernozem-like meadow and chernozem-meadow soils are recognized, depending on the degree to which the meadow and chernozem processes are indicated within the profile. The first subgroup is genetically related to meadow soils, the second to alluvial-meadow soils.

Chernozem-like meadow soils differ from meadow soils by a further recession of hydro-

morphic characters. In particular, in the lower part of B Horizon or in C Horizon of these soils, the olive-colored and bluish-gray mottling becomes less apparent. Humus content in upper levels is 3.5%-6.4% depending on relief and total nitrogen content is 0.18%-0.23%. C:N ratio is no more than 9-11.

Chernozem-meadow soils resemble chernozems very much in structure and physical and chemical make-up. They show the following characteristics: 1) a very distinct interdependence and delineation of genetic horizons; 2) considerable thickness (A + B is 80-90 cm, varying from 60-110 cm); 3) presence of sufficiently distinct illuvial-carbonate horizons, etc. They differ from the chernozems of western Ciscaucasia by the presence of hydro-morphic indications and of humus horizons at the depth of 1.5-2 m.

Humus content in the upper layer is on the average about 4%; it varies between 3% and 6%. Total humus content within the first 1 m is 400 metric tons per ha, just about the same as in typical meadow soils. But, unlike the latter, it is more uniformly distributed throughout the profile. Total N content in the plowed layer is 0.23%-0.27%. C:N ratio is about 10-12.

In conclusion it should be mentioned that solonchak and solonetz soils of the flood plain and delta of the Kuban River are not discussed here, since a somewhat short description of these soils appeared in a recent publication (2).

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⁶In the flood plains and deltas of other rivers, these soils were described as grassland-meadow, grassland-meadow granular, etc. According to Vil'yams these are the "granular soils" of the central flood plain.

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CLASSIFICATION OF SOUTHERN CHERNOZEMS OF THE CRIMEAN STEPPES

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Southern chernozems are the most important soils of the northern, lower and arid part of the chernozem zone of the Crimean steppes, which is distinguished by its smooth relief. Here bedrock is covered by a thick layer of quaternary deposits. The erosional pattern is developed very little. The valleys of the small rivers (Salgira, Indola, etc.) are not very deep and do not stand out in the general background. Ground waters are very deep and do not exert any influence on soil formation. Parent materials are loess-like, calcareous clays; more than 70% are particles smaller than 1 mm in diameter and contain 10%-14% of CaCO_3 .

Because of the influence of the extensive Ukrainian steppes, this part of the peninsula has a more arid and continental climate. Evaporation is considerably higher than precipitation, which amounts to 350-300 mm.

In the past the entire territory was covered by *Festuca-Artemisia* steppes. Their vegetation was characterized by narrow-leaved sod-grasses (*Festuca sulcata* and others) and low forbs (*Artemisia*, *Kochia* and *Bassia*). At present all virgin lands have been plowed and are under grain and commercial crops. The soils of this part of the chernozem zone are uniform and almost everywhere they consist of fine-textured, humus-poor southern chernozems which, under normal conditions of deposition, are fairly constant and dependable in their morphological characteristics, composition and properties. Farther north, in the area transitional to the chestnut zone, solonetzic southern chernozems and solonetz soils appear; thus, soils become more complex.

In order to illustrate the basic features of morphology of chernozems, a soil profile from the Crimean Experimental Agricultural Station of the Krasnogvardeiskoe district is described below.

Flat, wide, medium-hollow watershed. Fallow field. HCl effervescence begins at a depth of 40 cm. Depth of the entire profile

220 cm. Horizon A - 0-32 cm, A + B - 60 cm. CCaCO_3 - 60-110 cm. Carbonates appear under the form of white specks; the maximum accumulation occurs at a depth of 65-85 cm; sulfates appear at a depth of 150 cm.

Ap 0-20 cm. Gray, with a distinct chestnut hue, fresh, coarse-clay, somewhat compacted. It is often very much dispersed (powdery-dust); sometimes it tends to coalesce; after a rain it becomes covered on its surface by a compact crust. In fields that have been left in fallow, shows a foliar-scaly structure (result of overgrazing). The layer transitional to Horizon A is penetrated by roots and can be recognized by its color, structure and compactness.

A 20-32 cm. Dark-gray with a chestnut hue, fresh, more compacted, coarse-clay, blocky granular structure. Structural units angular with smooth, shiny facets. Size of units 1-1.5 cm. They are not stable. The stable aggregates are 3-5 mm in diameter. Transition to Horizon B gradual.

B₁ 32-40 cm. Brownish-gray, fresh, coarse clay, blocky. Structural units 1 to 1.5-2 cm, shiny when fractured. Compact, slightly cracked. Roots are present. Transition to Horizon B indicated by color.

B₂ 40-60 cm. Unevenly colored. Yellow-brown with humus streaks. Effervesces copiously beginning with depth of 30 cm. Fresh, coarse-clay, compacted, cracks (mainly in a vertical direction). Breaks up into structural units and is pierced by roots. Transition to Horizon C indicated by the appearance of white specks.

CCaCO_3 60-110 cm. Yellow-brown, humus streaks seldom present. Fresh, coarse-clay, very compacted. Breaks up into units or blocks 2-3 cm in size. Beginning with the depth of 60 cm, abundant, distinct, well-formed white specks appear (in concretions of 1-1.5 cm in diameter, not very compacted, farinaceous, white). The maximum of its accumulation

SOUTHERN CHERNOZEMS OF CRIMEAN STEPPE

urs at a depth of 65-95 cm. Visible calcium
umulations are absent below 110 cm.

C 110-150 cm. Coarse-clay, yellow-brown,
ormly colored, fresh, calcareous, loess-
e, compacted, small-porous.

Cs 150-220 cm. Light clay, yellow-brown,
sh, calcareous, compacted, finely porous,
h streaks and nodules of small crystals of
sum.

often equal to 6.2-6.5 (in virgin soils it in-
creases to 8). Total N content fluctuates
between 0.29%-0.25%. Total N content within
the plowed layer is not more than 7 metric
tons/ha.

As it appears from Table 4, adsorption
capacity fluctuates between 35-33 meq and
attains its highest value below the plowed layer.
Among the exchange cations Ca predominates
(85% of exchange capacity).

Table 1

Particle-size analysis of southern chernozem on quaternary loess-like deposits,^a
% of weight of dry soil

Locality	Depth, cm	Hygro- scopic water, %	Loss dur- ing the pre-treat- ment, %	Particle diameter, mm					
				<0.05	0.05- -0.01	0.01- -0.005	0.005- -0.001	< 0.001	<0.01
Krasnogvardeisk	0-10	6.01	0.856	1.68	27.28	7.71	13.80	49.89	71.40
rayon, Crimian	20-30	6.88	0.942	1.49	26.59	8.16	14.53	51.02	73.71
Oblast', Klepinino	40-50	6.26	10.52	1.54	27.34	7.56	14.19	49.51	71.26
Agricultural	63-73	4.63	18.78	1.68	26.77	6.99	13.35	51.74	72.08
Station	110-115	4.96	15.67	1.76	27.36	6.85	12.35	51.93	71.13
	160-173	7.93	14.94	1.42	28.07	6.71	13.60	50.56	70.87

According to the method of N.A. Kachinskiy

Quaternary deposits are the parent material
of southern chernozems and for this reason,
the soils (Table 1) have the same fine-texture
(staly clay).

The total amount of particles smaller than
1 mm in diameter at all horizons is more
than 70%, clay particles (smaller than 0.001 mm
in diameter) 50%. Particles larger than 0.25
mm are absent. The soil mass is well micro-
regated throughout the entire profile (Table
1). The coefficient of dispersion, which varies
very little throughout the genetic layers, is
10-20% (it increases only very slightly with
depth).

In organic material and nitrogen content, the
southern chernozems are considerably poorer
than the chernozems of the high Crimean steppe.
In plots cultivated for a long time the humus
content in the plowed layer is not more than
1.5-3%; in abandoned fields it increases to
4.5% (Table 3). Total humus content is 260-
300 metric tons/ha.

Nitrogen content within humus is very high.
A particularly small C:N ratio is character-
istic of fields cultivated for a long time; it is

Carbonate distribution is as follows. The
humic-eluvial Horizon A is always leached of
carbonates. The HCl effervescence usually
occurs in the second half of Horizon B; on the
average it appears abruptly at a depth of about
40 cm. In level areas, the depth at which effe-
rescence occurs, changes very little over wide
areas. From the depth of 45-50 cm on, car-
bonates appear abruptly in large amounts. Thus
in the upper part of Horizon B the carbonate
content is 8%-9%. The carbonates do not form
any visible accumulations since carbonate
pseudo-mycelia and molds are generally absent
in southern chernozems, especially in the north-
ern part of their distribution. The carbonate
content continues to increase farther down,
rapidly attaining its maximum at a depth of 70-
80 cm in horizon C CaCO_3 , where it amounts to
14%-18%. At this horizon there are always
bright, distinct, abundant white flecks. Between
110-120 cm the white flecks disappear and the
carbonate content begins to decrease gradually.
In Horizon C, at a depth of 170 cm, it attains
only 10%-12%.

Among the carbonates, CaCO_3 predominates
(Table 5), especially in the carbonate illuvial
layer; MgCO_3 is present in small amounts.

Nevertheless, in comparison with the chernozems of the southern, more elevated part of the steppe, the proportion of $MgCO_3$ among the carbonates, is considerable here.

As the data concerning the water extracts (Tables 6, 7) indicate, the southern chernozems profile is leached of easily soluble salts to a depth of 150-160 cm. Below this depth, gypsum, with a considerable admixture of sodium and magnesium sulphates, is present. The amount of the solid residue within the layer of maximum salt accumulation attains more than 1%.

Southern chernozems belong among the better arable soils of the Crimean steppes. Under

water regime. Their chemical indexes are given in Table 8.

Organic material is the most characteristic and essential part of the soil, upon which soil fertility chiefly depends. Southern chernozem are poor in humus, especially in fields cultivated for a long time, where its amount in the plowed layer barely surpasses 3% and the total content is 230-240 metric tons/ha. Since humus is the main source of nitrogen and other elements required for plant growth and also the main factor influencing soil structure, it is impossible to maintain high productivity in the soils without excellent soil management. Together with excellent agricultural practices, i

Table 2

Particle-size and micro-aggregate composition of southern chernozem on quaternary loess-like deposits, % of weight of dry soil

Locality	Depth, cm	Type of analysis	% of particles of diameters in mm of					Coefficient of dispersion ^b	Total amt. of aggr. larger than 0.01 mm diameter
			> 0.05	0.05— —0.01	0.01— —0.005	0.005— —0.001	< 0.001		
Krasnog-vardeisk rayon, Crimean Oblast', Klepinino Agricultural Station, fallow	0—10	Micro-aggregate Particle size ^a	2.09 1.68 +0.41	44.00 27.28 +16.72	20.12 7.71 +12.41	24.89 13.80 +11.09	9.23 49.89 —40.63	18.70	17.13
	20—30	Micro-aggregate Particle size	2.30 1.49 +0.81	45.34 26.59 +18.75	17.42 8.16 + 9.26	25.23 14.53 +10.70	9.17 51.02 —41.85	17.97	19.59
	40—50	Micro-aggregate Particle size	2.85 1.54 +1.31	44.85 27.34 +17.51	18.51 7.56 +10.95	26.01 14.19 +11.82	9.25 49.51 —40.26	18.69	18.82
	63—73	Micro-aggregate Particle size	2.03 1.68 +0.35	44.02 26.77 +17.25	91.28 6.99 +12.29	23.96 13.35 +10.61	10.46 51.74 —41.28	20.21	17.60
	110—115	Micro-aggregate Particle size	1.73 1.76 +0.03	48.84 27.36 +21.48	16.42 6.85 + 9.57	25.26 12.35 +12.91	10.84 51.93 —41.09	20.87	21.51

^aAccording to the method of Kachinskiy

^bThe coefficient of dispersion was calculated by means of the formula $\frac{B \times 100}{a}$, where a represents the particle size data and b the micro-aggregate analysis.

favorable weather conditions high yields of grain, commercial and other crops are obtained from them. But they are somewhat less fertile than chernozems of the high steppe and are poorer in total content of humus, nitrogen and phosphorus. Moreover, they have less favorable physical properties of soil and more extreme

is necessary above all to maintain a positive nitrogen balance. This will be accomplished by using all rational means to provide nitrogen: large amounts of manure, green manuring, mineral nitrogen fertilizers and utilizing alfalfa cultivation where irrigation is available.

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Table 3

Chemical analysis of southern chernozem on quaternary loess-like deposits

Locality	Genetical horizon	Depth, cm	Hygroscopic water	Humus (according to Tyurin)	Total nitrogen	C : N	CaCO ₃
			In Percent				
Krasnogvardeisk Rayon, Crimean Oblast', Klepinino Agricultural Station, fallow	A _p	0—10	6.01	3.19	0.296	6.25	none
	"	10—20	6.05	3.06	—	—	"
	A	20—30	6.34	2.67	0.256	5.97	"
	B ₁	30—40	6.88	2.10	—	—	"
	B ₂	40—50	6.26	1.79	—	—	12.06
	C _{CaCO₃}	63—73	4.63	1.15	—	—	21.5
	"	110—115	5.46	—	—	—	17.30
Krasnogvardeisk Rayon, Crimean Oblast', Klepinino Agricultural Station Virgin Reserve	C _s	160—173	6.93	0.73	—	—	14.43
	A	0—7	4.96	4.69	0.336	8.09	none
	"	7—16	5.39	3.93	—	—	"
	"	16—26	5.85	2.95	—	—	"
	"	26—36	6.19	2.54	0.254	5.78	"
	B ₁	36—43	5.98	2.32	—	—	"
	B ₂	43—55	5.19	2.12	—	—	3.5
Dzhankoi Oblast', "Michurin" kolkhoz	C _{CaCO₃}	65—75	4.37	1.29	—	—	15.4
	A _p	0—10	5.53	3.09	0.279	6.42	none
	"	10—20	5.47	3.10	—	—	"
	A	20—30	5.44	2.85	—	—	"
	B ₁	30—40	5.88	2.57	0.252	5.43	0.37
	B ₂	40—50	5.83	1.96	—	—	9.27
	C _{CaCO₃}	70—80	4.72	1.30	—	—	14.32
	C	127—138	4.32	0.90	—	—	11.57
	C _s	170—175	6.54	0.73	—	—	9.79

Table 4

Adsorption capacity and exchangeable cations of southern chernozems on quaternary loess-like deposits

Locality	Depth, cm	Content of exchangeable cations				Adsorp- tion capacity, meq	Percentage of composition	
		Ca ⁺⁺		Mg ⁺⁺			Ca	Mg
		In %	In meq	In %	In meq			
Krasnogvardeisk Rayon, Klepinino, fallow	0—10	0.566	28.3	0.052	4.33	32.63	85.7	13.3
	20—30	0.603	30.15	0.056	4.70	34.85	86.5	13.5
Dzhankoi Oblast', "Michurin" kolkhoz	0—10	0.529	26.44	0.056	4.63	31.97	85.0	15.0
	20—30	0.557	27.85	0.062	5.21	33.06	84.2	15.8

s Tyurin (21) shows, manuring at a rate of 0.0 metric tons/ha can provide considerable amounts of nitrogen needed to attain grain yields 0 cntr/ha and at the same time can reduce depletion of soil humus, thus maintaining a tant level (providing the required nitrogen

does not exclude the addition of other fertilizers, especially those containing phosphorus).

Southern chernozems are poor in phosphorus. According to our data, the total content in easily soluble phosphoric acid in the plowed layer is

Table 5

Quantitative carbonate composition of southern chernozem in percentage of oven-dry soil

Locality	Depth, cm	Carbonic acid	Total amount of carbonates	CaCO ₃	MgCO ₃	In percentage of total amount	
						CaCO ₃	MgCO ₃
Krasnogvardeisk Rayon, Crimean Oblast', agricultural station, fallow	40-50	5.50	11.99	9.37	2.62	78.17	21.83
	63-73	9.60	21.39	19.13	2.26	89.5	10.5
	110-115	7.80	17.27	14.91	2.36	86.4	13.6
	160-170	6.50	13.30	11.91	2.39	82.0	18.0

3.0-2.5 mg.

Under the arid Crimean climate, the important and often decisive fertility factor is moisture. However, the moisture conditions of the Crimean steppes have been investigated very little and almost no data exists on this problem.

Only a general idea of the moisture conditions of the southern chernozems and of moisture dynamics under various crops throughout one calendar year can be obtained from the records of the Meteorological Station of Krasnodeisk region, located in the area of the Agricultural Experiment Station at Klepinino. Figure 1 shows that moisture conditions of southern chernozems

pass through two periods:

1. Autumn-winter-early spring moist period of moisture accumulation within the soil (November-March). The beginning of this period varies; in wet autumns it begins in October, while during dry autumns, it may begin in December or even January.

2. Summer arid period (April-September, October). Since temperatures decrease in autumn (October, November), moisture loss through evaporation decreases sharply when rains begin; gradual soil moistening occurs beginning with the surface and proceeding downwards. This moistening attains its maximum

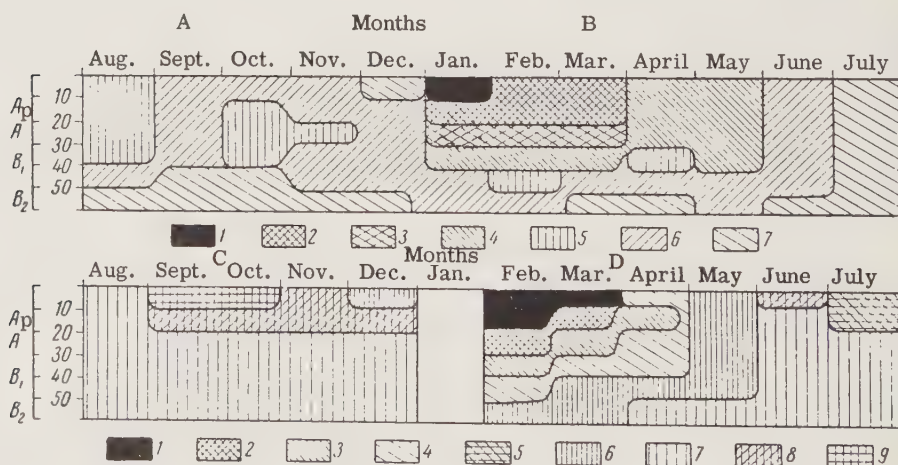


Fig. 1. - Moisture dynamics of southern chernozem (Krasnogvardeisk Rayon, Klepinino).

A - Fallow; B - Winter wheat. Moisture content higher than wilting: 1 - 33%; 2 - 33%-26%; 3 - 26%-24%; 4 - 24%-22%; 5 - 22%-20%. Moisture content lower than wilting: 6 - 20%-18%; 7 - 18%-15%. C - Wheat stubble; D - Spring wheat. Moisture content higher than wilting: 1 - 27%-28%; 2 - 25%-24%; 3 - 23%-21%; 4 - 20%-18%. Moisture content lower than wilting: 5 - 18%-16%; 6 - 15%-14%; 7 - 14%-12%; 8 - 11%-10%; 9 - 7%-8%.

Locality	Depth, cm	Solid residue, %	Alkalinity			SO ₄ ⁼		Cl ⁻		Ca ⁺⁺		Mg ⁺⁺		Na ⁺ and K ⁺ by difference	
			CO ₃ ⁼		HCO ₃ ⁻	In %	In meq	In %	In meq	In %	In meq	In %	In meq	In %	In meq
			In %	In meq											
Krasnogvardeisk Rayon, Crimean Oblast', agricultural station, fallow	110—115	0.056	0	0.046	0.75	0.002	0.04	0.004	0.11	0.007	0.35	0.003	0.25	0.007	0.32
	160—173	1.210	0	0.029	0.48	0.814	16.94	0.0042	0.12	0.255	12.77	0.012	0.989	0.086	3.78
Dzhankoi Oblast', "Michurin" kolkhoz	127—138	0.098	0	0.032	0.52	0.035	0.73	0.004	0.11	0.016	0.80	0.004	0.33	0.005	0.23
	170—175	1.190	0	0.026	0.43	0.793	16.53	0.004	0.12	0.255	12.77	0.010	0.875	0.08	3.44

Table 7

Salt composition of the sulfate layer of southern chernozem in percentage of oven-dry soil (on the basis of water extract)

Locality	Depth, cm	Solid residue, %	Ca(HCO ₃) ₂	CaSO ₄	MgSO ₄	Na ₂ SO ₄	NaCl	Total amt. of salts, %
Krasnogvardeisk Rayon, Klepinino, fallow	160—173	1.210	0.038	0.834	0.058	0.259	0.007	1.196
Dzhankoi Oblast', "Michurin" kolkhoz	170—175	1.190	0.034	0.839	0.052	0.235	0.007	1.167

February-March. When the moisture content within the upper layer attains 33%-27%, moisture transfer from the upper layers to the deeper ones occurs. The moisture content increases 20% to a depth of 40-60 cm.

In April, as the warm spring season arrives, crops begin to grow and develop. A rapid drying of the soil takes place, which is slowed somewhat only by the June rains, but in general, summer precipitation has little effect on soil moisture. Toward the end of summer, southern chernozems dry out every year to a considerable depth below the level of the wilting moisture; the steppe becomes burned out and does not revive until autumn. Black fallow, when properly cultivated, loses considerably smaller amounts of moisture during summer. The lower limit of moisture, within the surface layers of the fallow, is 20%-18% (i.e., it does not go below the level of the wilting moisture). The

Table 8
Chemical indicators of southern chernozems on quaternary loess-like deposits

Locality	Depth, cm	Depth of effervescence	Thickness of A + B	Total					Available		Total humus content, metric tons/ha	Adsorption capacity, meq	Range of active moisture		Wilting moisture, %	Total of wtr-stbl aggreg., diam. 1-5 mm
				Humus	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O			In % of weight of dry soil	In cubic m/ha		
Krasnogvardeisk P. Crimean Oblast, cultural station,	0-20	40	60	3.4	0.296	—	—	0.013	0.0030	0.024	74	32.63	18	432	16.5	1.8
	20-40			2.47	0.256	—	—	0.010	0.0025	0.016	52	34.85	6.6	174.24	19.5	22
Dzhankoi Oblast, "Michurin" kolk	0-20	35	60	3.1	0.279	0.039	1.74	0.012	0.0030	0.028	74	31.07	—	—	—	—
	20-40			2.57	0.252	0.038	1.69	0.011	0.0020	0.018	57	33.06	—	—	—	—

greatest decrease in moisture occurs within the plowed layer and especially within its upper part (0-10 cm). Here moisture is easily lost through evaporation but is often supplemented through summer rains. In winter the moisture content of this layer is higher than the minimum moisture capacity and during the period of maximum aridity, it attains 7%-8%, i.e., it is only slightly higher than hygroscopic moisture.

The improvement in moisture conditions of southern chernozems may be achieved by means of an increase in humus content, improvement in structure and by adopting all agricultural practices conducive to accumulation and conservation of soil moisture.

The material presented here indicates that in the Crimean steppes, as one moves north into the lower part of the plain, the following changes occur. The relief becomes smoother and the possibility of occurrence of loess-like deposits increases. Rather important is the change in climatic factors and in their regime. Climate becomes more arid and more continental. A change in vegetation also occurs. The feather-grass steppe gives place to an *Artemisia-Festuca sulcata* steppe.

With the change in the condition of soil formation, soil changes also. A gradual accumulation of new quality indicators occurs, indicators which characterize arid, non-chernozem steppes. Thus, in the chernozems of the low steppe the thickness of the humus layer decreases and so does the humus content. The layer of maximum carbonate accumulation is nearer to the surface and the rate of carbonate transfer is considerably slower.

The layer, in which HCl effervescence takes place, is very distinct and in most cases occurs at a depth of 40 cm. The accumulation of carbonates under the form of molds and pseudomycelia does not occur. The layer of carbonate accumulation as white flecks is thinner (its width decreases to 50-40 cm). The flecks are abundant and distinctly delimited. The layer of sulfate accumulation is also less deep and undergoes some change in composition because of its content in manganese and base cations. Adsorption capacity decreases; it attains its maximum in the layer immediately under the plowed layer. The entire adsorption complex changes, tending toward an increase in exchangeable manganese and in special cases, also in sodium. These changes promote colloidal transfer. The first indications of heterogeneity in the profile texture appear in southern chernozems (it is more distinct in solonchic types), and as a result there are some changes in soil profile.

Horizon A of the low steppe chernozems (in the non-cultivated area) has a two-layer structure: its upper part is quite different from the lower in color and compaction. The structural

ts lose the characteristic common to chernozems. They become angular, sharp-canted and air water-stability is lowered. The profile becomes more compacted and more susceptible to cracking. The hydro-physical properties, namely porosity, moisture capacity and permeability, are reduced considerably. The range of active moisture becomes narrower.

Together with the lower content in organic material, the total content in biologically important elements (nitrogen, phosphorus, trace elements) decreases. Conditions favorable to soil microorganisms are reduced and, in consequence (together with the reduction in water-air regime), fertility also decreases. In southern chernozems, especially during arid years, poor yields are common.

Considering all properties and peculiarities of southern chernozems, mentioned previously, it is possible to consider these soils as transitional to dark-chestnut soils. In our opinion, they should not be identified with chernozems that occupy more southern, more elevated, and drier parts of the Crimean plain, as these soils reflect rather clearly all basic traits of the chernozem-forming process in their aspect and properties.

The chernozems of the high steppe show certain characteristics peculiar to them (15) and possess a number of features that bring them near the chernozems of the eastern Ciscaucasian region and, in part, the chernozems of the Mozdok steppe (13)¹ (low humus content, medium bulk density, presence of mycelium, molds, white flecks, sulfates). Southern chernozems of the Crimean steppe, which develop under a more arid and continental climate, have a different status. These soils resemble very much the chernozems of the arid steppes of southern Ukraine in their morphological indicators and physical-chemical properties.

Among the general morphological characteristics of these soils are:

1. Small thickness of the humus containing layers. Average thickness of the humic Horizons $A + B_1 + B_2$ in Ukrainian chernozems transitional to dark-chestnut soils) is 55 cm, that of the Crimean chernozems 63 (55-68) cm.
2. Two-layer structure in the A Horizon.
3. Rather considerable compactness and appreciable cracking of the profile; small disturbance by soil organisms.
4. Absence of carbonates in the upper part of

Note: They may be considered as a more arid sub-type within the Ciscaucasian-Black Sea province of calcium-carbonated chernozems. Editor.

the profile. In Crimean southern chernozems, effervescence begins in B_1 Horizon; in those of the Ukraine, the beginning of effervescence coincides with the end of humic coloration in most cases. Carbonate mold and mycelium are absent. The layer of carbonate accumulation under the form of white flecks is quite distinct morphologically; it begins at a depth of 60-70 cm and is 50-60 cm thick.

5. Weak leaching of soluble salts. At a depth of 150-170 cm there occurs, without exception, a sulfate layer. Among the main chemical features, characteristics of both the Ukrainian and Crimean chernozems are:

a) a rather insignificant humus content, seldom higher than 3.5%-3.7% in old cultivated fields. Ukrainian southern chernozems, transitional to dark-chestnut soils, contain an average of 3.6%-3.7% humus in the plowed layer, those of Crimea contain 3.0%-3.2% humus. Humus content decreases sharply with depth.

b) sharp increase with depth in carbonic acid content.

c) Relatively low adsorption capacity; in Ukrainian chernozems the level varies between 31 and 40 meq, and in Crimean the level varies between 35 and 33 meq and attains its highest value immediately below the plowed layer. Among the exchangeable cations calcium predominates. The ratio C:Mg is 6-5. The amount of exchangeable Mg increases with depth. Content in exchangeable Na is very low.

In practice, in investigating Crimean chernozems, it is important to consider the diversity in their properties. Agricultural practices, fertilizer application and other measures to increase fertility must not be uniform for all chernozems of the Crimean steppes. They must vary according to the properties and characteristics of each chernozem variety.

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METHODS

ACCUMULATION OF PHOSPHORUS AND POTASSIUM WITHIN LEAVES OF TREES AND SHRUBS AND THEIR LEACHING FROM LITTER DURING THE AUTUMN-WINTER PERIOD

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The problem of increasing the productivity of forest plantations is hampered considerably by an insufficient knowledge of the small biological turnover of plant mineral nutrients. This problem is important chiefly because forest plantations grow for a long time at the same place, and also because every year they return to the soil surface a considerable portion of elements obtained from the soil. The rapidity of the liberation of these elements from the litter and their repeated utilization by plants determine to a considerable degree the possibility of their systematic replenishment within the plantation; because of this, the productivity increases of plantations.

Among these elements potassium and phosphorus play an important part in plantation productivity. The content in these elements is limited within most soils, and they are replenished very little through the weathering of parent material. According to Rode (6) the upper layers of forest soils, podzolized to various degrees, contain 0.81%-2.24% of K_2O and 0.05%-0.38% P_2O_5 . These amounts, even as total amounts, must not be considered high, but they are further reduced when considered in available quantities and are much smaller.

The importance of potassium and phosphorus in plant physiology is well known. Thus, according to Ratner (5) potassium influences the photosynthetic process greatly, although it does not form part of the photosynthetic products itself. Physiological research has further established that potassium affects the dispersion of protoplasmic colloids, their water content, viscosity, elasticity, etc., which in turn determine the degree of plant resistance to low or high temperature (winter hardiness) and to drought regime (drought resistance).

Even more varied and important to plants is the part played by phosphorus. It shares in the composition of protoplasm, cell nucleus and many ferments that regulate biological processes within plants. Phosphorus, under the form of phosphoric acid, participates directly in the

processes of respiration and fermentation (2) and also in the process of photosynthesis. According to Kursanov et al (3), the movement of carbohydrates in plants and, in part, their transport from leaves to storage organs, is influenced by phosphoric acid.

The importance of potassium and phosphorus in the vital processes of the trees and shrubs in forest plantations requires the investigation of both the seasonal plant requirements in these elements and of the amounts and the rate at which they are liberated from litter leaves and needles. Unfortunately, these problems have been investigated little.

During the years 1955-1957, research was conducted on the dynamics of accumulation of ash elements in growing leaves and needles of a number of trees and shrubs and their liberation from forest litter during the winter period (from the time of defoliation to the beginning of new growth). The method of research was relatively simple. Every month immediately from the beginning of full opening of leaves, in specially selected experimental areas, tree leaves (needles) were picked from almost all trees in various parts of the crown (to achieve objective data). The collected leaves were dried the same day and after having been ground were stored in a dry place until the time of analysis. In order to avoid dust contamination, the leaves were thoroughly wiped before drying.

In order to ascertain the rate at which potassium and phosphorus are leached out of the litter, it was collected at the time of mass defoliation and again in spring of the following year, when trees and shrubs began their vegetative activity. The preparation of the litter for analysis was the same as that of green leaves.

The analysis of leaves for potassium and phosphorous content was carried out by the department of forest crops of the Bryansk Forest Institute. Potassium was extracted by 1 N solution of sodium chloride after 24 hours of treatment. This extracted both the soluble and

exchangeable potassium. Its quantitative determination was done by means of the Pieve procedure using the cobalt-nitrite sodium method of the smallest concentration of precipitate. Phosphorus was extracted from the ground litter or leaves by a 0.2 N solution of hydrochloric acid, its content determined by colorimetric method. Analysis and calculation refer to air-dry material. In order to determine the amounts of phosphorus and potassium in litter or leaf substance, their content in ash was determined by means of ignition in the oven at red incandescence.

The accumulation of ash elements within the leaves is strictly correlated with local conditions. Research took place in the nursery of Beloberezh in the forestry department of the Bryansk Research Forest, where in 1948-1949 shrub seed plots were started. The nursery soil is poor, medium-podzolized, sandy, overlying fluvio-glacial sands, fresh. Because of depletion through plowing, the humus content in the A Horizon is low - 2.1%. Research also included three permanent experimental plots planted with pine, 36-40 years old, of the Karachinsko-Krylov forest of the same farm.

Experimental Plot No. 4 was in a pine-euonymus forest in relatively dry, shallow, sod-calcareous, clay loam soil underlain at a depth of 0.3 m by a chalky marl. Experimental Plot No. 5 was located in a pine-basswood forest with fresh, weakly-podzolized, sandy soil, underlain at a depth of 1.1 m by glauconite sands with phosphorites. Experimental Plot No. 7 was located in a forest of pine-Vaccinium; here the soil was peaty-medium-podzolized, sandy, with indications of gleying and with the presence, at a depth of 0.8 m, of phosphorites. The ground waters reach to the surface in autumn and in spring, and in summer descend to 0.5 m.

A short description of trees of the pine plantations, in which the experimental plots were located, is given in Table 1.

The results of the investigation of the total content in ash within the leaves of trees and shrubs that grew in the nursery are given in Table 2. As can be seen in this table, the ash content within the leaves of all species increases gradually from the opening of the leaves to the end of the growing season and defoliation. Except in two cases (pine and *Amorpha*) the increase amounts to 4%-87%, on the average 33%, of the initial ash content. It can also be observed that at the beginning of the growing season, the ash content within the leaves attains a considerable amount, 3%-11%, but in the majority of species it is 4%-7%. At the beginning of the growing season, together with leaf growth, there is a sharp increase in their ash content, which amounted to 0.25%-0.7% daily between April 27 and June 10, 1956. Considering the great number of leaves, such an intensive increase indicates that the period of leaf development is a time of great stress in relation to the plant requirements as regards the ash elements.

The accumulation of ash within the leaves continues throughout the following growing season, but the rate of increase is smaller. The increase in ash content during this time amounts to 0.01%-0.02% on the average; the maximum is 0.06%. But, because of the long growing season, this ash content increases in fall considerably. The ash content of leaves of shrubs (understory canopy) is somewhat higher (6%-7%) than in tree species (3%-6%).

Table 2 shows that the decomposition and leaching of the organic substance from the overwintering litter is somewhat more rapid than the leaching of the ash elements, which brings about an accumulation and increase in ash elements. In the majority of species the ash content increased 2-3 times, although in individual cases this increase was small (hazelnut, oak, etc.).

Habitat has a great influence on ash accumulation within leaves. Table 3 shows that the ash

Table 1
Characteristics of forest stands of the experimental plots
in pine plantations
(Karachizhsko-Krylovskoye forest of the
Bryansk Forest Research Station)

Characteristics of stands	Experimental plots		
	No. 4	No. 5	No. 6
Designation of plots	54-b	58-b	80-k
Age of a plantation (years)	36	44	32
Average diameter, cm	15.8	26.3	14.2
Average height, m	15.8	23.4	13.2
Crown cover	0.94	0.81	0.97
Number of stems per ha	1850	700	1700
Site quality index (according to Tyurin)	I	I-a	III

ACCUMULATION OF PHOSPHORUS AND POTASSIUM

Table 2

Ash content in leaves of trees and shrubs growing in the nursery of
Bryansk Forest Research Station (collection 1956)

Species	Ash content in % of air-dry weight and collection dates					
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	Litter for 1955
Mountain ash	4.53	4.92	5.86	5.74	6.89	12.40
Elder buckthorn	5.53	4.74	4.99	5.26	6.51	21.98
Small-leaf basswood	7.93	8.46	9.74	8.61	8.74	—
Hazelnut	7.53	6.83	8.09	7.59	9.25	10.38
Honeysuckle	5.44	4.95	6.83	7.69	—	—
European euonymus	11.01	9.94	8.90	11.30	12.68	—
Barberry	4.34	4.36	5.50	4.47	7.47	—
Star maple	4.01	3.99	5.00	4.92	6.04	11.71
Service berry	—	5.49	5.37	5.82	5.95	10.71
Privet	3.16	2.76	2.43	4.30	4.46	12.82
White dogwood	10—26	8.69	8.02	9.33	10.66	—
Red elder	9.78	10.85	11.91	12.14	15.28	30.78
Yellow acacia	7.37	7.75	9.52	10.71	10.12	12.48
Virginian cherry	4.60	5.00	4.71	5.62	6.57	11.88
Sylvestris pine (needles— one year)	3.02	2.42	2.15	2.38	2.72	—
Amorpha	4.79	3.58	4.36	4.31	4.27	10.34
Varty birch	4.40	4.99	3.93	4.72	4.67	—
Aspen	6.95	6.20	7.85	8.78	8.86	—
Siberian larch	3.45	3.26	3.43	5.03	6.44	—
Cherry oak	3.83	—	3.51	6.30	6.92	7.04
Lawthorne	6.61	—	7.23	7.24	7.91	12.64

Table 3

Ash content in leaves of shrubs and trees growing in pine plantations (collection 1956)

Species	Type of pine forest	Ash content in leaves in % of air-dry weight and collection dates				
		May 27	July 1	August 5	Sept. 5	Oct. 7
Mountain-ash	Vaccinium	8.61	8.88	8.47	8.45	7.86
	Euonymus	8.26	9.24	10.89	9.56	10.13
	Basswood	8.45	9.42	10.50	9.76	11.38
Elder buckthorne	Vaccinium	6.40	7.68	7.79	8.07	9.13
	Euonymus	—	7.52	9.66	9.35	10.86
Hazelnut	Euonymus	8.75	8.80	9.88	10.66	11.29
	Basswood	7.97	8.67	10.46	9.32	11.45
Euonymus	Euonymus	7.48	7.76	10.10	10.43	9.50
	Basswood	7.26	8.87	10.23	9.69	12.46
	Basswood	9.00	7.88	8.81	8.50	10.32
Small-leaf basswood	Basswood	8.76	6.71	7.83	8.11	10.24
Norway maple	Euonymus	—	7.51	8.84	10.78	12.37
Honeysuckle	Euonymus	10.54	10.04	16.46	15.78	15.08
White dogwood	Euonymus	9.75	12.17	15.24	15.57	15.31
Varty birch	Vaccinium	7.15	6.28	6.28	7.04	5.38
Aspen	Vaccinium	9.69	9.37	8.33	9.76	9.35
Gray willow	Vaccinium	9.21	7.41	9.27	10.75	10.31
Cherry oak	Vaccinium	—	4.86	5.45	6.21	6.48
Yellow acacia	Arboretum	7.54	8.05	12.20	12.13	12.87

content of the majority of species in pine plantations is considerably higher than in those growing within the nursery. Thus, for example, the ash content in the leaves of mountain ash is almost twice as high, and in other species 20%-40% higher. Also interesting is the difference in ash content according to the type of forest. The highest ash content was found in the species growing in the pine-basswood forest; it is somewhat lower in the pine-euonymus forest and lowest in the pine-Vaccinium forest. However, these differences are not too great and they appear only at the end of the growing season, when the ash content of some species attains 12%-15%. In spring the rate of increase is higher in pine plantations than in the nursery. The following summer-autumn period the increment rates are relatively uniform.

Potassium content in leaves of trees and shrubs, as can be seen in Table 4, varies within wide limits: 1.37%-0.31%; on the average, it is 0.5%-0.8%. It can be observed that species with higher ash content contain more potassium, although there are exceptions. Potassium content within leaf ashes varies from 3%-18.5%; on the average it is 10%-12%. The change in potassium content indicates that plants require, from the very first period of life, large quantities of potassium which amount to 14 kg for each metric ton of air-dry leaves, even in the poor nursery soil. Keeping in mind the short period of leaf

development (about 2 weeks), it follows that the increase in potassium content is rapid and that it attains 0.03%, or about 0.3 kg per day for a metric ton of air-dry leaves. In species with a low potassium content, these amounts are naturally lower and attain 0.1 kg per day.

During the growing season, the potassium content of leaves of trees and shrubs decreases gradually and noticeably in proportion to their age. Toward the end of the growing season this decrease reaches 0.2%-0.8% of air-dry leaves, or 19%-20% of the initial content. We may assume that during this period the transfer of potassium from the soil into the plant continues, but it is carried to other parts of the plant which grow at a greater rate (bark, wood) at this time. Potassium migrates there from the leaves, together with the products of assimilation. In this way the plant can accumulate in its non-deciduous parts a considerable amount of potassium, which is necessary to mobilize it rapidly and transfer it into growing leaves during the spring. With the falling of leaves only 60%-15% of the initial amount of potassium is lost to internal circulation; the remaining amount (40%-85%) is kept within the wood for re-use (re-utilization).

Potassium content within leaf ash also decreases accordingly; at the beginning of the growing season it attains 10%-12%, but as leaves grow (age) it gradually decreases to 2.5%-10%

Table 4

Potassium content in leaves of trees and shrubs growing in the nursery of the Bryansk Experimental Forest Station (collection 1956)

Species	Potassium in % air-dry leaf material					Potassium in % of ash content				
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	June 10	July 12	Aug. 4	Sept. 1	Oct. 1
Mountain ash	0.443	0.438	0.426	0.428	0.239	0.78	8.92	7.28	7.48	3.45
Alder buckthorn	0.860	0.465	0.460	0.453	0.164	15.55	9.83	9.23	8.61	2.52
Basswood	1.371	1.188	1.461	1.145	0.558	17.25	14.05	15.01	13.30	6.39
Hazelnut	0.952	0.746	0.724	0.727	0.444	12.64	10.92	8.95	9.58	4.30
Honeysuckle	0.307	0.231	0.146	0.202	—	5.65	4.67	2.14	2.62	—
Euonymus	1.371	1.200	1.132	1.221	0.727	12.43	12.07	12.72	10.80	5.74
Barberry	0.583	0.417	0.568	0.411	0.440	13.44	9.57	10.32	9.18	5.89
Service berry	—	0.690	0.658	0.658	0.440	—	12.56	12.26	11.30	7.40
Tatar maple	0.542	0.308	0.305	0.347	0.364	13.51	7.72	6.11	5.72	6.03
Privet	0.451	0.272	0.188	0.196	0.096	14.28	9.84	7.74	4.60	2.16
Dogwood	0.940	0.723	0.430	0.488	0.244	9.17	8.33	5.36	5.23	2.27
Elder	1.424	1.215	1.232	1.169	0.876	14.57	11.17	10.32	9.62	5.73
Acacia	1.178	0.972	0.805	0.810	0.732	15.99	12.53	8.45	7.56	7.23
Cherry	0.678	0.447	0.445	0.595	0.364	14.93	8.94	9.55	10.62	5.54
Pine	0.511	0.512	0.401	0.301	0.288	2.42	2.15	2.38	2.72	10.62
Amorpha	0.860	0.525	0.521	0.538	0.444	18.00	14.66	11.93	12.45	10.39
Birch	0.531	0.430	0.442	0.430	0.274	12.07	8.62	11.22	9.11	5.86
Aspen	0.713	0.602	0.611	0.554	0.361	10.26	9.72	7.79	6.31	4.08
Oak	0.892	—	0.892	0.438	0.191	18.45	—	25.40	6.96	2.67
Larch	0.428	0.317	0.317	0.307	0.228	9.79	9.72	9.25	6.10	3.54
Hawthorne	0.729	—	0.612	0.723	0.438	11.03	—	8.47	10.00	5.52

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the average 3%-5%) at the end of the growing season. The sharp decrease in potassium content is the result of the gradual increase in ash content in leaves and also of the decrease in absolute potassium content in leaves.

What has been stated previously is corroborated by Table 5, showing potassium content in leaves of plants growing in pine plantations. The total potassium content in young leaves in all forest types is considerably higher than in species growing in the nursery, where it attains 3% of the air-dry weight of leaves; in no species is it lower than 0.85%. In this case a metric ton of air-dry leaves contains on the average 13.5 kg of potassium.

The rates of increase and decrease in potassium content agree with those observed in the nursery. Potassium content in dying leaves is higher in this case than in the nursery. It is not higher than 0.25%; on the average it is about 60% of the initial content. Thus, when more potassium is available to plants, they divert a minor part of it for re-use. Potassium content in leaves is also somewhat higher here.

During the initial period of leaf growth, the amount of potassium in ashes is up to 23.4%. The differences in the amounts accumulated can be seen, for example, in mountain ash growing on all investigated plots. At the beginning of the growing season its ash content was 9.8% in the nursery; in the pine-Vaccinium forest, 13.8%; in the pine-euonymus forest, 14.2%; and in the

pine-basswood forest, 17.6%. The same holds true for other species.

The amount of phosphoric oxide within the leaves of various species growing within the nursery is shown in Table 6. Phosphoric oxide content in air-dry leaves is considerably lower than their potassium content and it varies between 0.13% and 0.33%.

The change in phosphoric oxide content in leaves is rather peculiar. At the beginning of the growing season it is high; in July and August it decreases, often to 40% of the initial content (Amorpha, aspen) and in September and October it begins to increase again until it almost equals the initial content. Thus, in addition to the first spring maximum of phosphorous requirement, there is a second, summer-autumn maximum, preceded by a migration of phosphorus during the second phase of growth. This peculiarity is important because almost all phosphorus accumulated during the first period subsequently disappears when leaves drop off. Table 6 also shows that the higher the phosphorous content in leaves, the more it decreases during summer; at low phosphorous content the decrease is relatively less. Thus, for example, in Amorpha containing 0.33% of phosphoric oxide (in air-dry leaves), in the middle of summer its content decreases to 0.1%, i.e., more than three times; simultaneously in mountain ash these amounts are, respectively, 0.14% and 0.12%; in larch, 0.16% and 0.14%; there has been a decrease of only 0.1%. It should be mentioned that, when

Table 5

Potassium content in leaves of trees and shrubs growing in pine plantations (collection 1956)

Species	Experimental Plot No.	Potassium in % of air-dry leaf material					Potassium in % of ash content				
		May 27	July 1	Aug. 5	Sept. 5	Oct. 7	May 27	July 1	Aug. 5	Sept. 5	Oct. 7
Mt. ash	7	1.802	0.960	0.949	0.730	0.442	13.75	7.88	11.20	8.65	5.63
	4	1.176	0.773	0.913	0.790	0.725	14.23	8.38	8.40	8.26	7.14
	5	1.485	1.423	1.180	0.858	0.742	17.59	15.13	11.23	8.80	6.52
Alder buckthorn	7	1.395	1.365	1.428	1.454	0.877	21.81	17.80	18.47	18.05	9.60
	4	—	1.656	1.462	1.458	1.080	—	22.00	15.14	15.63	9.95
Hazelnut	4	0.924	0.724	0.684	0.740	0.810	10.57	8.23	6.92	7.35	7.17
	5	1.240	0.962	0.815	0.779	0.656	15.56	9.95	7.77	8.35	6.72
Euonymus	4	1.745	1.130	0.953	0.941	0.739	23.35	14.56	9.42	9.03	7.78
	5	1.202	1.142	1.283	1.228	1.103	16.55	12.89	12.53	11.64	8.87
Basswood	5	1.740	1.835	1.660	1.308	0.888	19.35	23.25	18.85	15.39	7.82
Maple	5	1.785	1.055	0.927	0.875	0.568	20.40	15.73	11.85	10.79	5.53
	4	—	0.867	0.899	—	1.083	—	11.54	10.16	—	8.77
Honeysuckle	4	—	1.385	1.396	1.093	1.623	—	13.76	8.47	6.93	10.75
Dogwood	4	0.848	0.727	0.709	0.718	0.648	8.70	5.97	4.65	4.61	4.23
Birch	7	0.927	0.611	0.524	0.416	0.354	12.98	9.72	8.35	5.92	6.57
Aspen	7	1.391	0.914	0.921	0.893	0.359	14.36	9.76	11.05	9.15	3.84
Gray willow	7	1.386	1.111	1.078	1.023	0.427	15.07	15.00	11.64	9.54	4.14
Oak	7	—	0.735	0.599	0.552	0.247	—	15.13	11.00	8.90	3.81

Table 6

Phosphoric oxide content in leaves of trees and shrubs growing in the nursery of the Bryansk Experiment Forest Station (collection 1956)

Species	Phosphoric oxide in % of air-dry leaf material					Phosphoric oxide in % of ash content				
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	June 10	July 12	Aug. 4	Sept. 1	Oct. 1
Mountain ash	0.136	0.138	0.124	0.165	0.161	3.01	2.81	2.12	2.88	2.34
Alder buckthorn	0.248	0.239	0.202	0.221	0.234	4.49	5.05	4.05	4.20	3.59
Basswood	0.206	0.195	0.196	0.165	0.184	2.80	2.31	2.01	1.92	2.14
Hazelnut	0.133	0.139	0.142	0.246	0.362	1.77	2.04	1.76	3.24	3.91
Honeysuckle	0.333	0.196	0.243	0.253	—	6.13	3.97	3.12	3.30	—
Euonymus	0.325	0.248	0.244	0.264	0.389	2.95	2.48	2.74	2.24	3.07
Barberry	0.216	0.171	0.298	0.151	0.370	4.97	3.92	5.42	3.38	4.95
Tatar maple	0.248	0.140	0.147	0.214	0.201	6.16	3.51	2.94	4.35	3.33
Service berry	—	0.188	0.174	0.212	0.266	—	3.43	3.24	3.64	4.47
Privet	0.206	0.158	0.136	0.198	0.182	6.51	5.58	5.59	4.60	4.07
White dogwood	0.281	0.212	0.267	0.214	0.251	2.74	2.44	3.36	2.30	2.36
Red elder	0.319	0.284	0.195	0.222	0.281	3.26	2.62	1.64	1.74	1.84
Yellow acacia	0.282	0.280	0.196	0.417	0.234	3.83	3.62	2.06	3.89	2.31
Cherry	0.234	0.194	0.152	0.177	0.195	5.08	3.89	3.23	3.15	2.97
Pine	0.145	0.125	0.074	0.072	0.130	4.70	5.17	3.44	3.02	4.79
Amorpha	0.329	0.200	0.139	0.098	0.144	6.87	5.59	3.19	2.27	3.37
Birch	0.183	0.226	0.229	0.231	0.268	4.16	4.54	5.83	4.89	5.74
Aspen	0.244	0.194	0.145	0.136	0.163	3.51	3.13	1.85	1.56	1.84
Larch	0.164	0.139	0.160	0.221	0.205	4.75	4.26	4.67	4.40	3.19
Oak	0.258	—	0.190	0.193	0.189	5.34	—	5.41	3.07	2.73
Hawthorne	0.232	—	0.160	0.176	0.186	3.51	—	2.22	2.43	2.34

leaves drop off, the content in phosphorus does not increase to the initial amount. The initial amount varies between 1.25% and 0.70%; for 21 species it is on the average 1.06% and extremes are exceedingly rare. It is entirely possible that the differences are due to the lack of agreement of observational data on the maxima and minima of the phosphoric oxide content in the leaves of various species.

The relative content in phosphoric oxide in leaf ash does not go beyond 6.8%, while at the same time, the content in potassium is 18.5%. The changes in phosphoric oxide content in ash during the growing season are not very apparent, as they are masked by the steady increase in ash content of the leaves. In autumn the phosphoric oxide content within ash decreases to 0.5%-0.6% of the initial content (oak, aspen, elder).

Phosphoric oxide content in the leaves of species growing in pine plantations was higher than in those growing in the nursery (Table 7). Thus, for example, phosphoric oxide content in the leaves of mountain ash growing in the nursery was 0.136%; in this same plant growing in pine-Vaccinium forest it was 0.188%; in the pine-basswood forest 0.262%; in the pine-euonymus forest 0.276%. Phosphoric oxide content varies during the growing season even

in species growing in the nursery. It decreases in mid-summer (July-August) and sometimes in September (basswood). The second maximum in autumn is also very distinct. The degree of decrease in phosphoric oxide during summer varies; in special cases it is considerable (hazelnut in the pine-euonymus forest; aspen in the pine-Vaccinium forest). In this case it is 60%-62%. At times it is less, about 30% (honeysuckle in the pine-euonymus forest). The restoration in phosphoric oxide content in leaves at defoliation is of the same magnitude as in the nursery (0.75%-1.25%), but in special cases it decreases to 0.37% (aspen). On the average it is about 0.9% of the spring content for 18 species.

At the beginning of the growing season phosphoric oxide content in the leaf ash varies between 2.2% and 6.6% (on the average about 3.5%-4.5%). This is considerably lower in species growing in the nursery. This can be explained mainly by the high ash content of leaves and species growing in pine plantations. Because of the relatively small rate of increase in ash content in autumn, the peculiarities of change in phosphorous content in ash are rather distinct, but these changes are less conspicuous than in air-dry leaves. The relative content in phosphoric oxide in ash decreases sometimes to 0.4%-0.5% of the initial content.

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Table 7

Phosphoric oxide content in leaves of trees and shrubs growing in pine plantations of the Bryansk Experimental Forest Station

Species	Experimental Plot No.	Phosphoric oxide in % of air-dry leaf material					Phosphoric oxide in % of ash content				
		May 27	July 1	Aug. 5	Sept. 5	Oct. 7	May 27	July 1	Aug. 5	Sept. 5	Oct. 7
Mountain ash	7	0.188	0.064	0.124	0.125	0.150	2.18	0.72	1.47	1.48	1.91
	4	0.276	0.286	0.278	0.330	0.296	3.34	3.10	2.55	3.45	2.91
	5	0.262	0.183	0.171	0.175	0.335	3.11	1.94	1.63	1.80	2.94
Alder buck-thorn	7	0.396	0.235	0.196	0.232	0.254	5.77	3.06	2.52	2.87	2.78
	4	—	0.364	0.415	0.421	0.392	—	4.84	4.30	4.50	3.61
Hazelnut	4	0.258	0.104	0.163	0.190	0.328	2.95	1.18	1.65	1.89	2.91
	5	0.251	0.092	0.226	0.192	0.364	3.15	1.06	2.16	2.06	3.18
Enonymus	4	0.381	0.320	0.185	0.325	0.337	5.09	4.12	1.83	3.12	3.55
	5	0.476	0.317	0.329	0.333	0.425	6.55	3.58	3.21	3.44	3.41
Basswood	5	0.383	0.159	0.168	0.146	0.330	4.25	2.02	1.91	1.72	3.19
Norway maple	5	0.370	0.239	0.264	0.241	0.310	4.26	3.56	3.38	2.97	3.02
	4	—	0.336	0.348	0.398	0.296	—	4.70	3.94	3.69	2.39
Honeysuckle	4	0.362	0.236	0.322	0.284	0.344	3.46	2.35	1.96	1.91	2.28
White dogwood	4	0.397	0.314	0.300	0.268	0.349	4.07	2.58	1.97	1.72	2.28
Birch	7	0.250	0.148	0.139	0.173	0.148	3.50	2.36	2.22	2.46	2.75
Asper	7	0.396	0.138	0.151	0.153	0.147	4.09	1.47	1.82	1.57	1.58
Gray willow	7	0.385	0.217	0.216	0.234	0.160	4.18	2.83	2.33	2.18	1.55
Oak	7	—	0.177	0.154	0.237	0.153	—	3.65	2.83	3.87	2.36

Our data show that plants have a high potassium and phosphorous requirement during the period of leaf development, i.e., at the beginning of the growing season. Furthermore, potassium migrates partially into other plant organs and during defoliation not more than half of the total accumulated in spring returns to the soil. It appears that the plant might be saving part of its potassium for the following spring. Phosphorus behaves differently in this respect, since notwithstanding its partial summer migration, its initial content within is replenished in leaves and thus returns to soil in its entirety. Therefore, the plant extracts as much phosphorus from the soil in spring, as it has deposited into in autumn.

Together with the peculiarities of potassium and phosphorous requirement and return to soil, the behavior of these elements within the litter during autumn and winter, is of interest (from the end of one growing season to the beginning of the following one). During this time the transfer of ash elements from the soil into the plant is practically non-existent; simultaneously there occurs considerable precipitation, in the form of autumn rains and melt-waters which leach the litter and penetrate deep into soil. In the Bryansk forest this precipitation is about 240 mm.

In Table 8 potassium and phosphoric oxide content in fresh and wintered-over litter is given for some species growing in the nursery. As the

data indicate, potassium content in leaves decreased rapidly during winter from 0.88%-0.16% to 0.07%-0.03% of the weight of air-dry leaves; i.e., in the majority of species the amount of potassium remaining was 6%-8% (maximum 22%) of the initial content. During autumn and winter the litter loses from 78% to 94% of its potassium content. It should be mentioned that this amount is somewhat lower, since at this time both decomposition and leaching occurred, but the data given were calculated in relation to the remaining fraction of the litter. It is possible to assume that a considerable part of potassium, deposited into the soil in autumn, is irretrievably lost in soils having a small adsorption complex.

Phosphorus behaves similarly. During autumn and winter its content in air-dry leaves decreased from 0.36%-0.14% to 0.11%-0.03% and in the litter of the majority of tree and shrub species it was 10%-12% (maximum 37%) of the initial content. Its almost total leaching from sandy soils is even more probable than that of potassium, since phosphorus is adsorbed even less than the other ash elements into the adsorption complex and its fixation in the soil, as poorly soluble calcium and magnesium salts, is prevented by the highly acid medium and the small amounts of calcium and magnesium.

From what has been said, it is possible to conclude that a more rapid decomposition of litter during autumn and winter and the leaching

Table 8

Potassium and phosphoric oxide in fresh and over-wintered litter of trees and shrubs growing in the nursery of the Bryansk Experimental Forest Station (collection 1956)

Species	Potassium content, %					Phosphoric oxide content, %				
	Fresh		Over-wintered		Remain- ing on air-dry litter basis	Fresh		Over-wintered		Remain- ing on air-dry litter basis
	Litter					Litter				
	Litter basis	Ash basis	Litter basis	Ash basis		Litter basis	Ash basis	Litter basis	Ash basis	
Mt. ash	0.239	3.47	0.048	0.39	11.2	0.161	2.34	0.107	0.87	37.22
Alder buckthn.	0.164	2.52	0.048	0.22	8.7	0.234	3.59	0.082	0.37	10.35
Service berry	0.440	7.40	0.049	0.46	6.2	0.266	4.47	0.092	0.85	19.11
Maple	0.364	6.03	0.062	0.53	8.7	0.201	3.33	0.034	0.29	8.75
Honeysuckle	0.096	2.16	0.041	0.32	14.6	0.182	4.07	0.084	0.65	10.61
Yel. acacia	0.732	7.32	0.062	0.49	6.8	0.234	2.31	0.096	0.77	34.65
Elder	0.876	5.73	0.035	0.11	19.7	0.281	1.84	0.070	0.23	12.33
Amorpha	0.444	10.39	—	—	—	0.144	3.37	0.083	0.81	23.90
Cherry	0.364	5.54	0.046	0.39	7.0	0.195	2.97	0.055	0.46	15.55
Hazelnut	0.444	4.80	0.050	0.48	9.9	0.362	3.91	0.055	0.53	13.47
Larch	0.228	3.54	0.056	0.79	22.3	0.205	3.19	0.044	0.63	19.80
Hawthorne	0.438	5.52	0.074	0.58	10.5	0.186	2.34	0.065	0.51	21.79

of potassium and phosphorus from the root zone, is the negative factor from the viewpoint of re-utilization of the ash elements for plant growth. For this purpose a slow decomposition would be more appropriate. But a very slow decomposition, which would bring about a concentration of large amounts of ash elements, is also undesirable.

Moreover, this study shows that forest topsoil, especially its lower subhorizon, plays an important part in the accumulation of elements leached out of the litter. This layer has a high exchange capacity (150-160 meq) and has the ability to accumulate these elements in a form available to plants. When litter decomposes rapidly, the topsoil layer is thin, with a poorly developed subhorizon A_0^3 and, thus it is unable to keep the ash elements which are set free.

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VERTICAL NITRATE TRANSFER IN CHESTNUT SANDY LOAM-SOILS OF THE KULUNDA STEPPE

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Nitrate migration is of great scientific and practical importance. While this process is undoubtedly present in regions with high precipitation, as has been shown by many investigations, in the steppe zone nitrate transfer is limited to upper soil layers. Thus, according to Kudryavtseva (1) who summarizes the results of many experiment stations of the European USSR, nitrate migration in the chernozem belt does not take place below 50-70 cm. Therefore, the publication of Shopkhoyev (4), dealing with the vertical migration of nitrates in the chernozems of the Stavropol' region, is of great interest, as it agrees with our investigations of chestnut sandy loams of the Kulunda steppe.

During investigations in the years 1955 and 1956, we have determined the nitrate content during the growing period by means of the generally accepted method: in the plowed layer (0-20 cm) and in the sub-plowed layer (20-40 cm). However, in 1956, after a period of intense rains (during June the precipitation was 77 mm), determinations to the depth of 1 m (carried out as checks) showed that there was an intense leaching of nitrates, because of the coarse texture. The manner of their distribution throughout the profile permits us to suppose that the leaching process is not limited to the upper 1 m, but that it reaches into deeper layers.

In order to obtain a more detailed idea of the amount of leaching, from various fields of the "Stalin" kolkhoz (Kluchi subdistrict, Altai district) samples of soil and parent material were taken and analyzed to a depth of 2.5-3.0 m; i. e., down to layers that are under the influence of ground water. In several cases ground water was also analyzed.

The research was carried out on a virgin field, plowed 3 and 10 years ago, and on a plot plowed for a long time. Similar work was done on an adjacent irrigated plot and in the kolkhoz irrigated orchard. It should be mentioned that the chosen plots were not fertilized after plowing, with the exception of the kolkhoz orchard where phosphorous fertilizer was applied.

The investigated soils (chestnut sandy loams) occupy considerable areas of the Kulunda steppe, especially in the region adjacent to pine forest. In Horizon A₁ they contain 1.7%-2.5% of humus, 6-6.5 metric tons per ha of total nitrogen in the 0-100 cm layer; they are very permeable and have a low moisture capacity. The Kulunda climate is seldom arid; the average annual precipitation is 250 mm; maximum precipitation occurs in summer months.

Soil samples were taken with an auger from two parallel borings on plots of 30 m², especially established for this purpose. The nitrates were determined from freshly mixed samples according to Grandval'-Lyazhu and the moisture was determined by means of drying, at temperatures 100°-105°C, until a constant weight was achieved.

The results show that in virgin soil, where plant residues and humus mineralize relatively little and where nitrate nitrogen forms in small quantities, its transfer into lower layers is insignificant. The transfer is further limited by the fact that, in virgin soil which is comparatively drier than plowed soil, a larger degree of wetting would be necessary to produce a downward flow of water.

The transfer of nitrogen begins basically with plowing of virgin soil, when the water regime improves and the biological activity of soil rises rapidly. According to Table 1, there is a distinct correlation between the nitrate nitrogen content throughout the profile and the beginning of cultivation. Thus, virgin soil, plowed three years ago, still contains small amounts of nitrate nitrogen, while virgin soil, plowed 10 years ago, is similar in its nitrate nitrogen content, to plots plowed for a long time.

The process of nitrate transfer apparently occurs every year and is limited to the upper soil layers. Only in certain years, when the downward movement of water reaches the

Table 1

Nitrate nitrogen, mg per kg of oven-dry soil

Depth, cm	Virgin soil			Virgin soil, plowed in 1955. Wheat planting			Virgin soil, plowed in 1947. Corn planting			Field plowed for a long time. Wheat planting			Fd. pld. for a lg. time. Potato field
	May 16	July 17	Sept. 5	May 18	July 13	Sept. 3	June 15	July 24	Sept. 11	May 14	July 11	Sept. 2	June 6
0-10	1.4	3.4	2.3	18.2	7.1	2.3	54.9	19.0	11.1	34.7	3.2	0.8	60.7
10-20	0.4	3.3	2.6	10.1	3.5	2.4	63.0	21.8	5.2	30.0	3.2	2.4	56.5
20-40	0.4	2.5	2.5	4.2	3.2	2.5	52.3	18.1	3.8	21.3	6.4	10.4	61.9
40-60	0.4	3.9	1.1	4.1	3.3	11.8	59.8	19.4	1.9	7.7	3.2	9.2	55.1
60-80	0.4	4.0	1.1	3.4	2.7	11.3	79.2	22.2	1.8	3.5	2.0	1.9	69.5
80-100	0.4	3.5	0.8	2.7	3.7	10.1	63.1	20.7	1.8	2.6	0.7	1.7	62.3
100-120	0.3	4.4	0.8	2.4	1.9	2.3	46.8	20.2	1.8	12.2	0.5	1.0	53.6
130-150	0.2	4.2	0.8	1.3	2.2	2.3	45.7	20.0	Trace	7.6	0.5	Trace	52.5
160-180	0.1	3.8	0.8	1.2	1.5	2.4	42.0	20.4	"	62.4	0.5	"	51.3
190-210	Trace	4.0	0.8	1.0	1.4	3.4	46.2	20.0	None	63.7	0.5	"	64.3
220-240	"	4.1	0.8	0.9	1.5	3.1	50.5	19.2	"	63.9	Trace	"	46.3
250-270	None	4.0	0.8	0.5	1.3	3.2	—	18.8	"	64.2	"	"	45.0
280-300	"	—	—	0.5	1.1	2.3	—	—	"	40.3	"	"	49.2

capillary fringe, which in summer lies at a depth of 160-200 cm, can ground waters capture nitrogen. Analysis of ground waters has shown that their nitrate nitrogen content is 3.5-5 mg/l, which appears to be a rather high concentration.

Under irrigation the leaching of nitrate nitrogen is much greater, and it is the cause of impoverishment in nitrogen in chestnut soils (Table 2).

The transfer of nitrates into the lower layers is also possible with the so-called thawing moisture, which, according to Yarkov (5), brings about a decrease in moisture capacity in frozen soil. The existence of a downward flow of thawing moisture in the arid sections of the Kulunda steppe is mainly hypothetical, but it is probable, mainly when the preceding year had abundant precipitation. Such an assumption appears even more probable when one considers that in Kulunda a considerable

Table 2

Nitrate nitrogen, mg per kg of oven-dry soil

Depth, cm	Alfalfa						Irrigated orchard		
	non-irrigated			irrigated					
	June 24	Aug. 1	Sept. 7	June 22	July 30	Sept. 6	June 3	July 20	Sept. 10
0-10	80.9	2.6	2.4	18.2	1.4	1.6	4.9	2.5	1.0
10-20	74.0	5.7	2.5	29.2	14.1	2.2	1.9	None	1.1
20-40	71.9	3.9	1.0	14.5	4.5	1.5	0.3	"	1.1
40-60	61.7	2.4	1.0	3.3	1.2	1.1	0.3	"	0.9
60-80	60.0	2.4	0.9	2.2	1.2	0.9	0.4	"	0.8
80-100	57.7	3.0	0.7	2.3	0.7	Trace	0.3	"	Trace
100-120	59.2	2.2	Trace	1.8	0.7	"	0.4	"	"
130-150	51.9	2.8	"	1.6	0.6	"	0.3	"	"
160-180	61.2	2.6	"	1.7	Trace	"	0.3	"	"
190-210	54.9	2.2	"	1.8	"	"	0.3	"	"
220-240	61.4	2.2	"	1.8	"	"	0.3	"	"
250-270	64.9	1.3	"	2.1	"	"	—	—	—
280-300	60.2	2.4	"	1.8	"	"	—	—	—

VERTICAL NITRATE TRANSFER

Table 3

Precipitation (mm) during the 1957 growing season (Data from the Klyuchi Meteorological Station)

Month	10-day periods			Total for month
	I	II	III	
May	8.7	9.1	0.8	18.6
June	7.6	10.3	16.6	34.5
July	5.4	5.7	35.6	46.7
August	30.6	37.1	5.8	73.5
September	1.6	0.0	0.0	1.0

Table 4

Field soil moisture (% of soil weight)

Depth, cm	Determination dates					
	Virgin soil			Old plowed field. Wheat planting		
	May 16	July 17	Sept. 5	May 14	July 11	Sept. 2
0—20	6.9	2.1	3.6	9.6	2.7	7.7
20—40	3.4	2.3	3.5	8.1	3.5	7.3
40—60	3.8	1.9	3.4	5.3	2.7	7.0
60—80	5.0	3.4	3.1	4.0	2.3	3.4
80—100	4.0	2.0	2.3	2.5	3.1	3.4
100—120	2.4	1.0	2.1	2.6	1.9	3.4
130—150	2.3	1.0	2.1	2.1	1.5	2.1
160—180	2.2	0.9	2.7	1.4	0.5	1.8
190—210	2.4	2.9	3.8	0.5	0.3	1.7
220—240	2.0	3.0	4.1	0.7	1.0	2.5
250—270	1.9	4.2	4.9	2.8	2.8	2.9
280—300	2.1	4.6	8.6	3.4	3.8	4.4

se of ground waters toward the surface occurs in winter. Thus, according to Mosienko (2), in the wet year of 1954, during the period between November 5, 1954 and March 20, 1955, 100 m³ of moisture per ha were accumulated in the upper 1 m layer because of this rise.

It is difficult to say what the leaching rates of nitrate nitrogen are in any particular case, but they cannot be large. It is well known (and has been more confirmed through our research) that nitrates almost completely disappear in autumn and that their amount barely increases in winter.

The abundance of nitrates in the lower layers of the chestnut soils may be explained by their gradual transfer from the upper layers, especially during the thawing of the soil and also when summer rains occur in the form of heavy down-

pours. This last fact is particularly important, since our investigations of 1955 and 1956 indicate that in the upper layers of the investigated soils, up to 90-95 mg of nitrate nitrogen for each kg of soil accumulate under the vegetation in certain periods.

The distinct change in nitrate nitrogen content in the lower soil layers and in the parent material, is interesting. According to Tables 1 and 2, its maximum amount in the entire profile of the chestnut soil occurs toward the end of spring and at the beginning of summer. In the middle of summer it begins to decrease and disappears in fall. Since the disappearance of nitrates occurs during a period of strong drought, Tables 3 and 4, it cannot be explained by their leaching into deeper layers.

In the case investigated, biological nitrate absorption appears most probable, although the possibility of formation of insoluble nitrogen compounds during this period, as mentioned by Shmuk (3), is not excluded.

Conclusions

1. In chestnut sandy loams of central Kulunda leaching of nitrate nitrogen occurs under dry-land conditions.

2. The leaching process is barely noticeable in virgin soil and abandoned fields, but it increases rapidly in intensity upon plowing.

3. Nitrate transfer may occur in spring or in summer in wet years after abundant rains. With irrigation, leaching of nitrates is very intense, and consequently, large portions of them go to ground waters.

4. It has been found that nitrates disappear in summer during the dry period to a depth of 2-3 m. In the case investigated, biological

absorption of nitrates is probable.

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MOVEMENT OF SOIL MOISTURE AND ITS AVAILABILITY TO PLANTS

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The manner in which plants secure soil moisture has been investigated very little. At present, four principal types of soil moisture are recognized on the basis of its availability to plants (12).

1. Moisture that is practically unavailable to plants. Its upper limit corresponds to wilting moisture (WM).

2. Moisture that is available to plants with difficulty. Its amount lies in the interval between the wilting moisture and the moisture at breaking of capillary continuity (MBC). The movement of this moisture in available form is limited, a fact which makes its use by plants difficult.

3. Moisture is medium-available to plants. Its amount is within the interval between the moisture at the breaking of capillary continuity and the minimum (or field) moisture capacity (MM). Medium-available moisture is considerably mobile and the plants utilize it regularly.

4. Easily available moisture, becoming superfluous at times is that moisture which lies between minimum moisture capacity and saturation moisture capacity (SM). This moisture is highly mobile, but it exists in the soil for only a short time.

It is apparent that in this classification the availability of moisture to plants is entirely unrelated with its mobility, and the level of moisture at which capillary continuity is broken, separating the productive moisture from the unproductive that is available to plants with difficulty.

Regarding the availability of moisture between MBC and WM, Rode (12) states: "Within this interval of moisture plants can exist without a sign of lack of water, but at the same time the productivity of vegetation remains at a fairly low level" (p. 398). Dolgov (4) adds: "Free water under conditions of broken capillary continuity is available to plants with

difficulty; the transition from free water to this state during the drying of soils brings about permanent wilting of plants; even the transpiration rate is lowered" (p. 191).

In view of these statements, it is interesting to consider Abramova's (1) investigations of the level of moisture between MM and MBC in relation to soil texture and structure. According to her, this level amounts to 30% of the total moisture content in micro-structural soils at MM and in a structural chernozem it is 8%-3% of the soil weight, i. e., if MM of a structural chernozem in her experiment was 36%, then at BC it was 33% of the soil weight.

Since, when moisture level is lowered to MBC, the loss of moisture by evaporation through the surface decreases rapidly, Abramova's data have confirmed once more the well-known assumption of the great importance of soil structure in reducing harmful moisture losses through evaporation. But from what sources will the plant obtain its water when the moisture drops 3%, if the remaining moisture is available with difficulty because of its small mobility? Investigations have shown that structural soils make water available to plants more fully and for a longer time than non-structural soils, although this last type has a wider interval of available moisture.

The answer to this question is found in Kolyasev (6), who wrote in 1948: "... the effect of the capillary mechanism is quite limited; it is characteristic of soil moisture to drop below the level of field moisture capacity when the continuity of the capillary film is interrupted and the menisci remain only at the point of contact of soil particles. Moisture mobility decreases rapidly within the soil. If during the capillary state water reached into the root zone because of the moisture gradient, now the roots must search for water at the point of contact of soil particles. Thus more root hairs are developed which utilize a greater volume of soil."

The process of obtaining water by a growing

and advancing root system has been very graphically described by Maximov (9), Petrov (11) and others.

Thus, the interaction between soil moisture and plants must be based on the investigation, not only of the mobility of soil water, but also on the development of the root system. When soil moisture is high (higher than MBC) and therefore highly mobile, capillarity plays an important part in providing the root system with moisture. In this case it is not necessary for plants to develop a large root system. Therefore, many report a less developed and shallower root system when there is superfluous and normal moisture, than under conditions of insufficient moisture.

In the interval between the level of moisture at which capillary continuity is interrupted and the critical moisture at which the slowing of growth processes begins, moisture movement in liquid form is practically non-existent and the plants can obtain moisture only by developing their root system toward the loci of moisture accumulation. In this regard it is interesting to mention that all drought-resistant varieties of any plant have, as a rule, a larger and better developed root system and that, finally, the drought resistance of a given variety cannot be explained by any particular case through movement of soil moisture.

As the moisture level decreases further, the root system is not able to extract from the soil the moisture needed for growth and development. This brings about a slowing up at first and, later, a complete cessation of growth and the break-down in all physiological processes taking place in plants during normal moisture availability and, finally, wilting.

Such an interpretation of the mechanism of interaction between soil moisture and plants makes the need for good availability of water to crops growing in structural soils understandable.

A structural soil has the advantage of a considerably low surface evaporation when its moisture content reaches the level at which capillary continuity is interrupted (MBC). Even at this level, a large amount of moisture remains in this type of soil which, even if almost immobilized, is still easily available to a rapidly growing and developing root system. A structural soil continues supplying plants with moisture, almost until all available moisture has evaporated.

In non-structural soils, the mechanism of obtaining moisture by plants is evidently the same. But in these soils the interruption of capillary continuity occurs much later, when almost all of the moisture needed for growth and development is gone.

In considering the processes of inter-relation between soil moisture in liquid form and the plants in the interval between MM and WM, it is necessary, in our opinion, to consider the role of moisture in vapor form in the distribution of moisture throughout the soil profile and its availability to plants.

This is particularly important since some investigators (4, 7, 10) mention that the participation of water vapor in the transfer of water becomes important only when the soil dries out to the level of WM or below, and that its part in providing plants with moisture is insignificant; other authors (3, 11, 13) are inclined to recognize a more important role of vapor moisture in water transfer throughout the profile and its supply to plants.

Apparently, there are no direct experimental data in literature on the amount of vapor moisture movement at different levels of soil moisture. Therefore, we consider it of interest to dwell here on some factual data obtained in the summer of 1955 while investigating moisture evaporation from soil surface on the training farm of the Voronezh Farm Institute "Otradnoye." The following methods were employed.

Surface evaporation was determined by means of small evaporimeters made by a group of co-workers of VNIIGiM under the leadership of Zhegalov. The evaporimeters were cylinders, 10 cm in diameter, 25 cm in height, filled by a column of soil and closed at the bottom by a reticulate or solid cover. Evaporation measurements by (by weighing) were taken in the morning and evening (at 7 and 19 hours) directly under field conditions at the site where samples were obtained, with a technical balance (precision of weighing 0.5-1.0 g). After the experiment the soil from each cylinder was dried to a constant weight in an oven at a temperature of 100°-105° C and the soil moisture in each cylinder was calculated each day.

Analysis of the results shows that the weight of the evaporimeters with a reticulate bottom increases considerably during the night. Into an evaporimeter containing soil with 26%-29% of moisture (80%-90% of MM) during the night entered 30%-50% of moisture, which evaporated during the day (Table 1). The influx of moisture into the upper soil layers during the night at high soil moisture content (after irrigation) is mentioned also by Burman and Perelet (2).

In what form, from where and why does the nightly influx of moisture into the upper soil layers take place? Since the increase in weight was found only in evaporimeters with a reticulate bottom (spacing of the mesh is 0.25 x 0.25 mm) which interrupted the capillary flow, while in evaporimeters with a solid bottom there was a nightly decrease of 1-2 g, it is possible to conclude that moisture was

MOVEMENT OF SOIL MOISTURE

Table 1

Evaporation (during the day) and influx (during the night) of moisture from data obtained by evaporimeter No. 1 (reticulate bottom)

Date	Observation period	Water evaporated during the day (g)	Increase in water content during the night (g)	Comparative soil moist. to the evaporimeter (% of soil weight).
Aug. 4	Day	13.5	—	26.5
Aug. 4-5	Night	—	7.0	26.3
Aug. 11-12	Night	—	8.0	29.0
Aug. 12	Day	19.0	—	28.7
Aug. 14-15	Night	—	10.0	27.8
Aug. 15	Day	27.0	—	27.4
Aug. 16	Day	10.5	—	26.2
Aug. 16-17	Night	—	5.0	26.0

Table 2

Soil temperature profile during 24 hours, June 2-3, 1955 (black fallow)

Hours	Soil temperature, °C, at depths in m				
	0.00	0.05	0.10	0.20	0.30
19	22.4	22.0	21.0	18.2	17.0
21	14.6	19.5	19.7	18.2	15.7
23	11.6	17.1	17.8	17.6	15.7
1	9.2	15.8	16.6	17.0	15.6
3	7.3	14.3	15.2	16.3	15.5
5	7.2	13.3	14.4	15.7	15.3
7	16.8	13.7	14.0	15.0	15.2
9	24.6	17.0	15.5	15.0	15.0
11	30.2	22.1	18.8	15.5	14.8
13	36.4	25.4	22.0	16.8	14.8
15	34.8	27.4	24.1	18.2	15.2
17	32.2	27.5	25.1	19.5	15.5
19	26.8	25.6	24.5	20.5	16.0

tained in the form of vapor from the lower layers of the soil.

The most probable reasons for the assumption of vapor movement and its condensation are the vertical soil temperature gradients which change twice during 24 hours (in summer). This is apparent, both from the data in Table 1 which refers to a typical, clear, warm day at the site of the experiment, and from the review of literature (5, 8). The presence of temperature gradients within the soil brings about an uninterrupted transfer of vapor moisture from the warm to the cooler soil layers.

During the day, when the soil surface warms considerably, vapor moisture is transferred,

as a result of temperature difference, into the lower layers of the soil profile.

The cooling of the upper soil layers during the night, reverses the temperature gradient and the flow of water vapor. As soil became drier, the amount of water lost through evaporation decreased in our experiments, but it has not been possible (with the precision of the scales available) to substantiate the influx of moisture into evaporimeters during the night.

The following conclusion may be made from the foregoing data: Vapor moisture participates actively in the distribution of water throughout the layers of a soil profile. This is particularly noticeable at high moisture content

within the soil (26%-29% of the soil weight). This vapor moisture plays an important part in establishing within the root layer of the soil amounts of moisture which the plants expend during transpiration.

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APPARATUS FOR DETERMINING THE AMOUNT OF CARBON DIOXIDE DIFFUSION FROM SOIL¹

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The processes of synthesis and decomposition of organic material in their seasonal and daily rhythms are expressions of the biological cycle (2). The amount of carbon dioxide involved in this cycle can be considered a measure of the intensity of the process.

It is well known that the final stage of decomposition and the initial stage of synthesis of organic material involve the same compound - CO_2 . If we consider this compound as an indicator of the rates of the complex conversions of organic substances, then we can state that the CO_2 production will be small in a soil of low fertility and, conversely, it will be large in a rich soil. Hence there is sufficient basis for assuming, as a working hypothesis, the existence of a regular quantitative relationship between the energy of decomposition and the energy of synthesis of organic material. Evidently this energy varies according to variations in soil-climatic conditions, and particularly to changes in the physical conditions surrounding the decomposition of organic material in the soil. If this is so, then it is possible to judge the effective fertility of a soil not only from the synthesis of organic material (yield) but also from its decomposition in the soil. The production of carbon dioxide in a definite period of time in the soil can also be used as a quantitative indicator of this process.

This point of view agrees with the opinions of Bussengo (1) on the close relationship between soil fertility and the CO_2 content in the soil, and also with the views of Kostychev (6) on the direct dependence of soil fertility on

the intensity of the activities of higher and lower plants.

Principles and Methods for Determination in Soil

All the methods of estimating the carbon dioxide produced in the soil under field conditions are based on determining: a) the CO_2 concentration in the soil atmosphere and b) the diffusion of CO_2 from the soil.

The methods based on the first of these principles differ regarding the method of sampling the soil atmosphere and its further analysis for CO_2 content. Thus, for example, in Kazin's method (5), the air is withdrawn from the soil with an aspirator through a cylinder previously imbedded in the soil with a cutting action. In the methods of Turlyun (11) and Vershinin and Poyasov (3) the air is withdrawn from the soil with a needle and analyzed in a gas analyzer. Finally, there is the method of Gorbunov (4), in which air from the soil enclosed in a cylinder is displaced with water.

The carbon dioxide content in the soil atmosphere is of only relative importance for judging the decomposition energy of organic material, and this does not hold for all cases by far because of the differences in gas exchange. Let us cite as an example the results of an experiment which we conducted on a podzolic coarse clay loam at the LOVIUAA Experiment Station at Antelevo, where the experiment involved different degrees of soil compaction (Table 1). The experiment treatments were as follows: 1) the soil was cultivated every ten days; 2) after cultivation the soil was allowed to compact naturally; and 3) after cultivation the soil was tamped. The plots were fallow. The air samples were taken with an aspirator through a cylinder cut 10 cm into the soil a month after the experiment was initiated. We see from the data in Table 1 that, if we judge the decomposition energy of organic material in the compacted soil (third

¹In offering a new original device for determining the carbon dioxide diffusion from the soil, the author conditionally assumes that all carbon dioxide given off by the soil is the decomposition product of organic material. But we must not overlook the portion of carbon dioxide that is the respiration of plant roots. The device offered is used to determine the decomposition energy of organic material in the soil and the respiration of roots. Editorial Board.

Table 1

The CO₂ content in the soil atmosphere in relation to the soil compactness

State of the soil	Experimental treatment	CO ₂ , mg/l of soil atmosphere
Loose	Control	3.21
	Manure, 160 metric tons/ha	7.01
Slightly comp.	Control	2.12
	Manure, 160 metric tons/ha	10.65
Compacted	Control	12.80
	Manure, 160 metric tons/ha	61.30

treatment) from the presence of carbon dioxide in the soil atmosphere, then we are led to an erroneous conclusion, since here the high CO₂ content is due to other causes, namely: the low gas exchange between soil and atmosphere, which favors the accumulation of CO₂ even when the decomposition energy is low (this is also characteristic of water-logged soils).

The methods related to the second group, i. e., those based on the determination of the CO₂ diffusion in the soil, are more interesting for our purposes. From these let us single out the method of Lundegardh, which utilizes a metal hood imbedded in the soil; the carbon dioxide diffusing from the soil inside the hood is absorbed by air drawn through it above the soil with an aspirator.

In Makarov's method (8), instead of Lundegardh's hood, a glass "booth" of quite large capacity is imbedded in the soil. After a short time a two-liter sample of air is removed from this chamber with an aspirator through an absorbing column, where the CO₂ is trapped.

Shtatnov's method (12) is simple in conception and equipment. In this method the CO₂ diffusing from the soil is absorbed by an alkaline solution located in a dish within a cylinder imbedded in the soil and covered above. The advantage of this method over the others is that the diffusion of carbon dioxide from the soil and its absorption take place naturally (without external interference), and the observations are made on the treatments simultaneously, a fact of importance in view of the changing rate of CO₂ diffusion during the day. However, because the laws governing the diffusion of carbon dioxide from the soil have been inadequately studied, even the most promising methods very often do not give satisfactory results. Thus, for example, no credit is offered the soil-produced CO₂ that is used to fill the pores and voids of the soil horizons. These are an important reservoir where, as we know from the work of Matskevich (9), a consider-

able amount of CO₂ can accumulate. No allowance is made for the effect of changes in barometric pressure on the diffusion of CO₂. This, as the convincing calculations of Smolenskiy (10) show, can greatly distort the true picture of CO₂ production in the soil, since previously accumulated carbon dioxide moves out of the deeper horizons as the atmospheric pressure is reduced.

In our method of determining the decomposition energy, we have followed a somewhat different way. We eliminate the effect of the deeper soil horizons on the index of the energy of decomposition and study processes isolated from them in the most active upper portion of the humus horizon together with the adjacent portion of the atmosphere. At the same time the natural structure of the soil sample is not disturbed.

Numerous tests of the apparatus have shown it to be convenient to use under both field and laboratory conditions.

The Diffusimeter and Principle of its Operation

The diffusimeter which we have built and used consists of three basic parts (Fig. 1).

A is a brass cylinder with a volume of somewhat more than 0.25 l; **B** is a gas-absorbing glass vessel with a capacity of about 0.5 l; and **C** is a regulator for maintaining atmospheric pressure in the apparatus.

The cylinder contains the soil with disturbed or undisturbed structure, depending on the problem under study. It accommodates a soil column 100 mm high and 25 cm² in cross-sectional area. Above the soil there is a free space 10 mm high to facilitate diffusion of the gases. At its upper end the cylinder is provided with an externally threaded throat for screwing on vessel **B**. Its internal diameter equals half the diameter of the cylinder. The lower

APPARATUS FOR DETERMINING CARBON DIOXIDE DIFFUSION

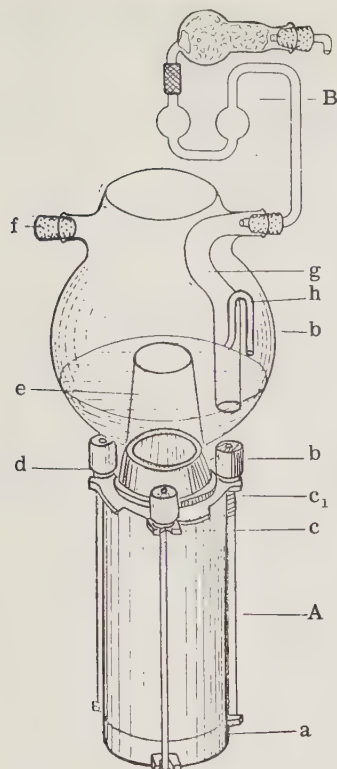


Fig. 1. - Diffusimeter for determining carbon dioxide produced in the soil.

part of the cylinder is closed with a removable cap (a) and a rubber gasket. The lower cover is attached to the body of the cylinder with three screw clamps (b), which are hinged to the cover. They fit into special notches above the cover (c). There is a rubber gasket between the cylinder and the vessel (c₁).

The purpose of the gas-absorbing vessel is evident from its name. In it the carbon dioxide diffusing out of the soil is bound. To absorb the CO₂ we use 100 ml of 0.03 N potassium hydroxide, added into the vessel through the narrow (15 mm) throat (d). Through this same throat the solution is also titrated after it has absorbed the CO₂. The vessel has a tube (e) of the same diameter as the throat of the cylinder. This tube extends 45 mm inside the vessel to retain the solution when the vessel is inverted while attached to the cylinder. This tube also permits exchange of air between the soil atmosphere in the cylinder and the air enclosed in the vessel. At the other end of the vessel are attached two oppositely positioned nipples (f). One of them is for removing liquids from the vessel; the other is a socket for the pressure regulator.

The final part in the vessel is a chamber (g) with a volume of about 10 ml. During operation of the apparatus its lower end is submerged 2-5 mm into the solution. Its purpose is to isolate the small volume of air in the chamber, which exchanges with the external atmosphere when the pressure changes (cf. below), from the carbon dioxide entering the vessel from the soil. At the level of the end of tube (e) the chamber (g) is provided with an arched 2-mm capillary (h) to equalize the pressure of the air in the chamber and in the vessel.

The regulator, which maintains the atmospheric pressure inside the apparatus, consists of two hollow globes joined by a 1-mm capillary. Two or three drops of glycerine are put into the capillary. This liquid is a block between the chamber and the atmosphere and moves from the capillary into one or the other of the globes, admitting air only if the atmospheric pressure and the pressure of the gas inside the vessel are different, chiefly as a result of temperature fluctuations. The other end of the regulator is fitted with a calcium chloride drying tube filled with soda lime, which absorbs carbon dioxide from the air drawn in from the outside atmosphere.

To insert and retract the cylinder from the soil a metal cap is used (Fig. 2, A). It consists of a tube provided with two connected handles and three lugs grooved on the inside face. The cap is placed on the cylinder lugs down and turned 45°; simultaneously the grooves of the lugs engage projections on the upper end of the cylinder; thus the cap is attached to the cylinder.

Before insertion into the soil the cylinder is fitted with a cutter (Fig. 2, B). For carrying to the field the vessels with the solution are placed in the compartments of a carrying case resembling a suitcase. When imbedded in the soil the cylinder can be used to determine the carbon-dioxide content in the soil atmosphere. For this, in place of the vessel, a cover with

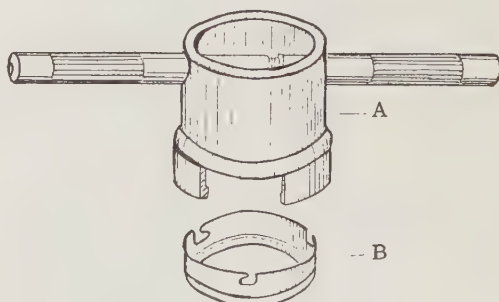


Fig. 2. - Metal cap (A) for imbedding the cylinder in the soil, and steel cutter (B).

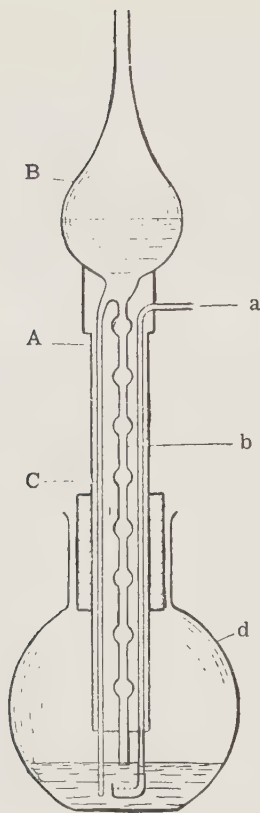


Fig. 3. - Absorbing column for CO_2 of soil atmosphere provided with circulation device.

outlet tube is screwed on the throat of the cylinder. Samples of the soil atmosphere are withdrawn with an aspirator. The carbon dioxide is absorbed by potassium hydroxide at the same concentration in the absorbing column of the apparatus shown in Figure 3.

Inside the tube (A), which is 20 mm in diameter and has a pear-shaped enlargement at its upper end (B), there are three smaller tubes. One of these (a), entering laterally, admits the air from the soil. The second (b), a capillary with globular swellings, connects above with the pear-shaped enlargement and during operation is filled with the alkaline solution. It lengthens the path of the air in the absorbing solution. The third tube (c), which is connected above to the capillary with the swellings, provides for the continuous circulation of the solution in the system, as is necessary for effective absorption of the CO_2 . The ends of all the tubes extend beyond the lower end of the absorber, while the end of the third tube (c) must be longer than the second (b). The end of the first, gas-carrying tube (a) is covered with a gas diffuser of porous

glass. This absorber, inserted in a rubber stopper, is introduced into a 100 ml flask (d) with 50 ml of titrated base.

Using the equipment described, observations can be made on the following phenomena that take place in the soil:

1. Production of carbon dioxide in the soil under field and laboratory conditions.
 2. Diffusion of carbon dioxide from the soil in the field.
 3. Dynamic concentration of carbon dioxide in the soil atmosphere.
 4. Change in the bulk density of the soil.
- By utilizing the data mentioned previously, it is possible also to determine:
5. Total porosity of the soil, and
 6. Effective air capacity of the soil - in the ordinary way.
 7. Air exchange in the soil.

Determination Methods

The CO_2 production in the soil is determined in the following way. After insertion into the soil the cylinder is withdrawn together with the soil inside; the cutter is removed; the excess soil is cut off; the lower cover is attached; and the cylinder with the soil is replaced in the ground to the same depth. Then the vessel with 100 ml of 0.03 N base is screwed on the neck of the cylinder and fitted with the regulator. After a day the cylinder and vessel are removed to the laboratory, where the amount of soil in the cylinder is determined by weighing as well as the volume it occupies. The bound carbon dioxide is determined by titration with 0.03 N hydrochloric acid and phenolphthalein, the results being expressed as mg of CO_2 per kg of dry soil-day.² At the same time the moisture and temperature change of the soil during the day are determined.

The diffusion of carbon dioxide from the soil is determined with the same apparatus but without the lower collar and the regulator. The data are computed in grams of CO_2 per square meter-day.

The data obtained in this way on the diffusion of carbon dioxide from the soil and on the CO_2

² For complete absorption of the CO_2 contained in the vessel, after separation from the cylinder the vessel should be shaken and allowed to stand a while before titration.

ment in the soil atmosphere can be used to calculate the air exchange (aeration) of the soil. In his time Kostychev (6) noted that among the principal conditions governing the composition rate of organic substances there are: moisture, temperature, and supply of air. But up to this time methods have not been developed for determining the rate of air exchange in soils under field conditions. We have tried in first approximation to fill this gap.

If we know the amount of CO_2 in mg diffusing from the soil into the atmosphere (q) in so many hours (t) over the cross-sectional area of the cylinder (S), and if we know the content of CO_2 in mg in 1000 ml of the soil atmosphere (Q), then the ratio $Q:1000$ expresses the content of carbon dioxide in 1 ml. Also, during the hour $\frac{q}{tS}$ mg of CO_2 pass into the atmosphere across 1 cm^2 of cylinder section. If we designate by A the amount of air passing from the soil in one hour across an area of 1 cm^2 , then the ratio $\frac{q}{tS}:A$ also expresses the content of carbon dioxide in 1 ml of the soil atmosphere. Thus $\frac{q/tS}{A} = \frac{Q}{1000}$, whence $A = \frac{q \times 1000}{t \times S \times Q}$.

If the amount of carbon dioxide $\frac{q}{t}$, diffusing in one hour across the sectional area of the cylinder is designated as P_d , and the quantity $\frac{1000}{S}$, which is constant for a given cylinder is designated as K , then we obtain the aeration $\approx \frac{P_d}{Q} \times K \text{ cm}^3 (\text{cm}^2) \text{ hr}$.

The operation of the equipment is illustrated in the results of some of our experiments given below.

CO_2 Production in Soil in Relation to Time of Day and Temperature

The questions regarding the amount of carbon dioxide accumulating in the soil atmosphere during the day and at night, at what time its loss from the soil to the atmosphere is greater, and, finally, whether there is a large difference in the decomposition energy of organic materials in the soil at these times of day, have not been completely clear. At the same time they are important for determining the number and hours of observation during the day. To study these questions a podzolic-gleyed clay silt loam topped to spring wheat was selected. The observations were made with a soil moisture 16%-17%. The soil temperature at a depth of 10 cm varied during the day in a range of $10^\circ\text{--}20^\circ\text{C}$. Readings were taken at 9 pm and 9 am. The data in Table 2 show that the energy of decomposition of organic substances in the soil and the air exchange are appreciably higher in the daytime than at night. The CO_2 content in the soil atmosphere is related in-

Table 2

Effect of time (in days) on the production of CO_2 in the soil

Observation dates	Experimental treatments	Experiment length, hrs	CO_2 , mg/l of soil atmosphere	Air exchange, $\text{cm}^3 (\text{cm}^2) \text{ hr}$	Energy of breakdown (mg CO_2 /hr and kg of soil)	CO_2 diffusion, $\text{g}/\text{m}^2/\text{day}$
July 10	Day	12	2.98	11.9	4.8	8.54
" 11	Night	"	3.24	10.6	3.4	8.26
" 11	Day	"	2.88	12.9	3.8	8.94
" 12	Night	"	4.17	7.8	2.7	7.76

versely to the process of air exchange.

The data presented permit the following conclusions to be drawn:

1. The supply of air to plants during the day is associated with a high enrichment of the air near the ground in carbon dioxide.
2. Soil processes having a higher content take place during the daylight hours, a fact evidently associated with the higher daytime soil temperatures.
3. The over-all balance of a soil process can be correctly depicted only by observing the full daily cycle, and this was accepted by us as a basis for making our CO_2 observations.

The effect of temperature on the energy of decomposition can be seen from Table 3. Undisturbed soils were taken from different tillage treatments. The following principle was noticed: if soil samples are arranged according to increasing degrees of decomposition energy at the lowest temperature, then the same order is preserved also at higher temperatures, while the difference in decomposition energy among the treatments increases with increasing temperature. Thus, the data of Table 3 completely support the assumption that temperature fluctuations during the day can have an appreciable effect on the decomposition energy and other phenomena associated with it, particularly air exchange, CO_2 concentration in the soil atmosphere, etc.

In support of what we have said earlier relative to the lack of studies on the phenomenon of CO_2 diffusion from the soil under field conditions, we offer the data in Tables 4 and 5. From these data we see the lack of agreement between parallel quantities describing the decomposition energy and the diffusion of CO_2 both from fine and coarse-textured soils.

Table 3

Effect of temperature on energy of decomposition of organic material in a podzolic coarse clay loam cropped to clover, mg CO₂/day/kg of soil

Soil moisture content, %	Average daily temperature, °C		
	7.5°	13.0°	22.0°
23.2	21.4	52.7	97.2
25.0	26.4	59.4	119.0
23.7	27.3	64.7	144.5
24.5	29.9	66.0	160.0

In order to check the results obtained and also the operation of the equipment, the observations on the third and fourth plots with coarse-textured soils (Table 5) were repeated after moving the apparatus from the third plot to the fourth and from the fourth to the third. The results of this check showed that the data on the energy of decomposition were quite stable but that the results on the diffusion of CO₂ from the whole soil profile were more variable.

Effect of Lime on Changes in Decomposition Energy of Organic Material in Soil

In order to explain the difference in the energy of decomposition of organic material

Table 4

Energy of decomposition of organic material in a loose and a compacted podzolic-gleyed clay cropped to spring wheat

Observation dates, 1952	Experimental variant	Physical state of the soil			Physical factors of soil formation			Indexes of the process		
		Bulk density	%, total porosity	Net air exchange, %	t°C of the soil at 10 cm depth with device set up in the soil	Moisture, % (moist soil)	Air exchange, cm ³ (cm ²) hr	CO ₂ , mg/l of soil atmosphere	Decomposition energy (mg CO ₂ /day/kg soil)	CO ₂ diffusion, g/m ² /day
June 27	Spring tilling to 20 cm	0.77	70.4	50.5	16.5	20.6	9.6	3.34	58.7	7.6
	Without tilling	0.94	63.8	33.1	16.0	24.6	5.5	6.29	56.0	8.3
Aug. 28	Spring tilling to 20 cm	0.91	62.9	17.9	12.2	33.0	1.2	13.89	66.7	4.1
	Without tilling	0.94	61.6	10.6	12.3	35.7	0.9	14.21	64.0	3.0

Table 5

Energy of decomposition and diffusion of CO₂ in a podzolic coarse clay loam cropped to clover

Observation dates, 1952	Plot No.	Physical state of the soil			Physical factors of soil formation			Indexes of the process		
		Bulk density	% total porosity	Effective air capacity %	t°C of soil at 10 cm depth with device located in soil	Moisture content of soil, % (moist soil)	Air exchange, cm ³ /(cm ²) hr	CO ₂ , mg/l of soil atmosphere	Decomposition energy (mg CO ₂ /day/kg soil)	CO ₂ diffusion g/m ² -day
Sept. 11	1	1.08	57.7	30.9	11.3	21.4	4.6	13.9	54.9	15.2
"	2	1.15	54.9	27.1	11.3	21.4	3.0	14.1	65.9	10.2
Sept. 16	3	1.07	58.2	29.7	6.2	21.1	4.8	14.1	36.8	16.5
"	4	1.11	56.6	26.2	6.2	21.5	4.1	13.5	43.6	13.1
Sept. 17	3	1.07	58.0	30.0	10.0	20.7	3.9	18.8	36.6	14.7
"	4	1.05	58.8	29.8	10.0	21.6	3.3	15.6	43.6	15.2

APPARATUS FOR DETERMINING CARBON DIOXIDE DIFFUSION

lime is added to the soil, 0.5 kg of a podzolized fine clay loam from a field of perennial grasses was placed in a 1-liter glass jar composted under optimal moisture conditions in a thermostatic apparatus for a month and a half.

period can be more correctly estimated from observation of the entire daily cycle.

4. The carbon dioxide produced in the soil can be considered as a sensitive indicator of the manifold changes that take place in the soil

Table 6

Effect of lime on energy of decomposition in podzolic-gleyed clay 1.5 months after composting

Experimental treatment	Moisture content, %	Length of experiment, days	Average temperature, °C	Decomposition energy (mg CO ₂ /day/kg soil)	% of control
Soil cropped to perennial grasses, 3rd year	29.7	4	15.7	45.9	100.0
Same + calcareous soil at 0.5 hydrolytic acidity	28.5	"	"	59.0	128.5

the findings, which are given in Table 6, that lime added to the soil at half strength (determined according to hydrolytic acidity), after a month and a half of composting, still increases the energy of decomposition by 28.7% relative to the control. This preliminary experiment shows that the energy of decomposition of organic material in the soil can be considered as a sensitive indicator of the effect of agricultural measures on the soil.

as a result of numerous agricultural measures: liming, cultivation, soil compaction, etc.

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Conclusions

A diffusimeter for determining the amount of carbon dioxide produced in the soil was constructed and used under field and laboratory conditions. Tests of the apparatus showed it to be satisfactory. The data obtained with this apparatus agree completely with other physical factors and the general theoretical aspects.

A formula is given for determining the exchange between the soil and the atmosphere under field conditions. It is based on the diffusion of CO₂ from the soil and the concentration of CO₂ in the soil atmosphere.

A number of experiments described in the present paper have made it possible to verify certain important principles. Thus, the decomposition of organic material, air exchange, and CO₂ diffusion from the soil are more vigorous during the day, and weaker at night. The concentration of CO₂ in the soil atmosphere increases at night. Therefore the general balance of the process over a 24-hr

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COMPARATIVE STUDY OF SEASONAL DYNAMICS OF THE COMPOSITION OF ORGANIC MATERIAL IN FRESH AND AIR-DRY SAMPLES OF BOG SOILS

A. NIKOLAYEVA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

In our recently published paper (2) we described the results of a study of the seasonal dynamics of the composition of organic material in drained and cultivated peat-bog soils of the Moscow Region Bog Experiment Station, located on the floodplain of the Yakhroma River. A description of the objectives of the investigation, the method of operation, and the results are given in the paper mentioned previously. We indicated that the next phase of our work would be a parallel study of the dynamics of the composition of organic material in fresh and air-dry samples. This study was to determine the extent of the differences in the analytical data for both and to find the best times for taking samples in the field in a single investigation of the composition of organic material in air-dry samples.

In addition to the methodology, this comparative study allows us to account for the effect of the composition and properties of the organic material in the soil of particular physical conditions, in this case drying. There are almost no data of this nature in the literature.

We ran our comparative study of the dynamics of the composition of organic material in fresh and air-dry samples on one of the soils studied earlier (Soil No. 56) in two replicates, four times during the growing season.

Soil No. 56, located in the central part of the floodplain of the Yakhroma River, is a low-humic-peaty, ferruginous soil on grassy-wooded (alder) peats, drained and cultivated approximately 30-35 years. For a long time the soil has been cropped to perennial grasses and mowed for hay. The samples of the soil were taken in 1956 on the following dates: April 13, June 20, August 5, and October 3.

The composition of the organic material in fresh and air-dry samples was analyzed according to a shortened Tyurin method (4, 5), namely: decalcification with a 0.1 N solution of H_2SO_4 - treatment in the cold 0.1 N NaOH; a

separate weighed portion of the soil was treated directly with 0.1 N NaOH and the data from the analysis of this extract were subtracted from the data from the analysis of the 0.1 N H_2SO_4 + 0.1 N NaOH extracts, as in the Tyurin method.

The results of the analyses, expressed in percents of the total content of organic C and N in the soil, are given in Table 1.

As we see from the analytical data, drying has a different effect on the solubility of the organic material in peat soils at different seasons of the year and in different horizons. In the layer from 0-10 cm it greatly increases the solubility of organic C and N in April and October, having no effect on the solubility of the organic material in June, and decreases its solubility somewhat in August.

In the layer from 30-40 cm the effect of drying on the solubility of the organic material is in many respects opposite to that observed in the layer from 0-10 cm. Thus, in April the data on the total solution of C and N from the moist and dry samples of the layer from 30-40 cm almost coincide. In June, however, they are quite different; drying in this case does not increase but reduces the solubility of C and N. Only on the later observation dates (August-October) does the drying increase somewhat the solubility of C and N in the layer from 30-40 cm.

The question arises: Are not the differences between the solubilities of the organic material in the moist and dry samples directly related with the moistness of the soil at the time the samples are taken?

In Figure 1 are plotted the data on the field moisture of the soils in percents of the absolutely dry peat material and the difference between the solubilities of organic C in the dry and moist samples as percents of the total C content. Positive differences are plotted above the x-axis, and negative differences below. We see that in

SEASONAL DYNAMICS OF ORGANIC MATERIAL

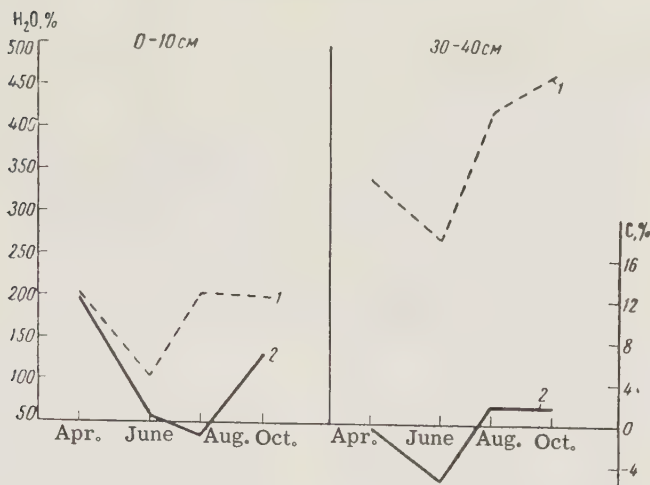


Fig. 1. - Relationship of the differences between analytical data for dry and moist samples on the field moisture of the soils.

general there is a dependent relationship between the field moisture content of the soils and the effect of drying on the solubility of the organic material, but it is not linear. Thus, in the layer from 0-10 cm the effect of drying in August and October is not correlated with the change in the field moisture content of the soils. In addition, the range of differences between the curves of soil moisture and the effect of drying is far wider in the layer from 30-40 cm than in that from 0-10 cm. All this shows that the effect of drying on the solubility of the organic material is governed not only by the field moisture content of the soil but also by other factors associated with the seasonal changes in the composition or properties of the organic material, which are to a certain extent independent of the soil moisture or overlap its effect.

A second question also can be asked: Are not the differences between the analytical data for the moist and dry samples the result of an unintentional composting of the latter while they are being air-dried? To this question we can reply negatively, since we spread the samples in a thin layer on paper and they dried in three or four days. The possibility that microbiological processes were activated while the samples were drying is also made unlikely by the fact that the effect of drying does not always run in the same direction. In our experiment we found all kinds of variations in the effects of drying on the mobility of the organic material.

Let us return to our discussion of the drying effect on the chemical and fractional composition of the organic material dissolved using the analytical procedure mentioned. In Figure 2 we divide the humic and fulvic acids into

those that are more mobile and soluble directly in 0.1 N NaOH and those that are less mobile and soluble in 0.1 N NaOH only after decalcification, as in Tyurin's procedure. On the basis of the data in Table 1 and Figure 2 we can make the following statements.

0.1 N H₂SO₄ extract. The solubility of the organic material in 0.1 N H₂SO₄ is 1.5-2 times higher in the air-dry samples as compared with the solubility for the moist samples. The C:N ratio varies insignificantly in the majority of cases.

0.1 N NaOH extract after decalcification. In the analytical procedure adopted by us, this extract, when added to the insignificant amount of organic materials dissolved in 0.1 N H₂SO₄, accounts for the total amount of C and N dissolved, the seasonal variations of which we have mentioned earlier. It is interesting to note that drying of the soil samples, in affecting the quantity of material dissolved in 0.1 N NaOH after decalcification, leaves its chemical make-up almost unchanged, especially in the layer from 0-10 cm. The ratio of the total amount of dissolved humic acids to the total amount of alkali-soluble fulvic acids here remains constant for the moist and the dry samples. In the layer from 30-40 cm this ratio changes somewhat after drying: in April and October toward an increase in humic acids, and in June and August toward an increase in fulvic acids. But in most cases, after drying, the humic and fulvic acids increase or decrease together in the 0.1 N NaOH extract from decalcified soil. At the same time the C:N ratio in the humic acids decreases somewhat, and increases in the fulvic acids.

The Tyurin procedure specifies that this

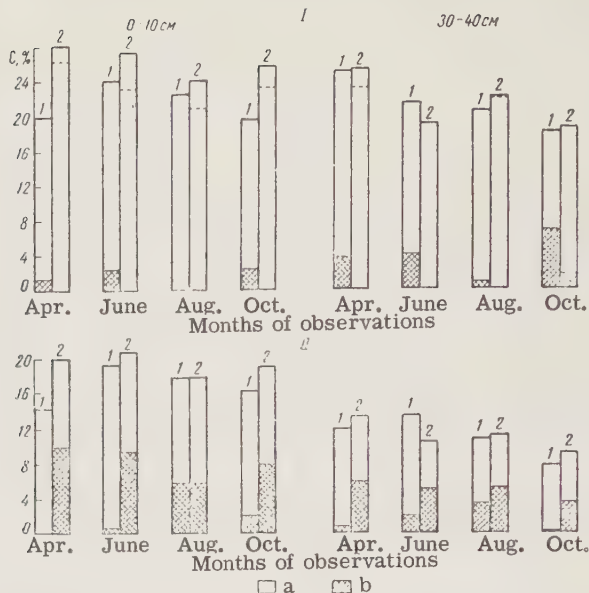


Fig. 2. - Comparative data on the chemical composition of the organic material in moist and dry soil samples.

I - Humic acids; II - fulvic acids. 1 - moist samples; 2 - dry samples. a - soluble in 0.1 N NaOH directly; b - soluble in 0.1 N NaOH only after decalcification.

fraction be subdivided into a more mobile portion directly soluble in 0.1 N NaOH and a less mobile portion soluble in 0.1 N NaOH only after decalcification. The quantitative relationship between these smaller fractions of the humic substances and their internal composition varies greatly in the dry samples as compared with the moist samples.

Direct 0.1 N NaOH extract. Drying of the soil samples has the most pronounced effect on the composition of this fraction. After drying, the humic acid content in this fraction rises appreciably, and that of the fulvic acids drops. This phenomenon is most pronounced in April; in June it is somewhat less strongly expressed; in August the analytical data for the moist and dry samples are almost equivalent; and in October drying again increases the humic acid content in the direct alkali extract and decreases that of the fulvic acids.

The changes in the composition of the direct alkali extract are reflected in the composition of the less mobile fraction of the humic substances soluble in 0.1 N NaOH only after decalcification and computed by difference. We see from Figure 2 that in the dried samples, as a rule, there is an appreciable increase in the content of humic acids in the first fraction soluble directly in 0.1 N NaOH, but there is a drop all the way to zero in the content of humic acids

in the second fraction, which is soluble in 0.1 N NaOH only after decalcification. The exact opposite is true for the changes in composition of the fulvic acid group. In the dry samples as compared with the moist, we find a drop in the fulvic acid content for the direct alkali extract and a corresponding increase in the content of fulvic acids soluble in 0.1 N NaOH only after decalcification. But we do not find a direct proportionality between the increase in some fractions or groups of humic substances and the decrease in others.

It is interesting to point out that the direct alkaline extraction removes a little more of the humic acids from the dried soil samples of the 0-10 cm layer, and sometimes from the 30-40 cm layer, than does extraction after decalcification. In Figure 2 the solution of the humic acids in 0.1 N NaOH after decalcification is shown by the hatched area. Such cases are sometimes observed also in the analysis of dry samples of mineral soils taken from areas with a moist climate.

Thus our results in general agree with the older data of agricultural chemistry, which emphasize the fact that soil drying makes organic material more mobile, providing a source of assimilable nutrients, and hence increases the fertility of soils, particularly bog soils (which have a high potential fertility). As

We have already said, however, drying has a different effect on the total solubility of organic material and its fractional and chemical composition at different times during the growing season. The effect on the organic material is greatest in April and least in August. In this connection we may conclude that the organic material in the soils we investigated reaches its most stable state as regards composition and properties in August. It is not impossible that similar phenomena occur also in other soils.

It is of interest to mention that during all other times of observations (April, June, and October), drying of the samples changed the organic composition in the same direction, moving it toward the composition of organic material characterizing the moist samples in August. But August was not the driest (as regards soil moisture) period of our observations; on the contrary, soil moisture at this time was very high. Hence we may conclude that the stabilized composition and properties of the organic material as observed under field conditions in August is governed, not by drying of the soil, but by regular, as it were, "developmental" changes in the composition and properties of the organic material during the annual life cycle of the soil. In bringing the soil samples taken at other times to the air-dry condition we artificially convert the organic material to the stable state natural-characteristic for August.

Summarizing our conclusions concerning the effect of drying soil samples on the state of the organic matter therein, we may say that, to a certain extent, it equalizes the seasonal variations both in the over-all solubility and in the fractional and chemical composition of the organic material as compared with the analysis of moist samples. This fact is of interest and important from the methodological point of view. It means that a single study of the composition of soil organic material in air-dry samples gives us more or less averaged data, regardless of when the samples are taken in the field. They are close to the data obtained from the analysis of fresh soil samples in the period of natural stabilization of the composition and properties of the organic material, i. e., in the second half of the summer. And the composition of the organic material in fresh soil samples is subject to considerable seasonal variation. Therefore, one-time, i. e., static determination, is best done with air-dry samples.

In support of this conclusion we can also give other arguments. In the statistical study of soils of different geographical regions it is very important to obtain and accumulate considerable analytical data. It can hardly be required that studies of the composition of the organic matter in the soil always be carried out on fresh samples, since very often they are

collected in places quite remote from the laboratory where they are analyzed. Prolonged storage of fresh samples of soil, for example in hermetically sealed containers, is likewise undesirable, since there will be a concomitant artificial composting of the samples, and that under anaerobic conditions. In short, single analyses of the organic material in soils from fresh samples, which must necessarily be taken at widely different times, would lead to results that are not comparable.

As for the study of the natural dynamic composition of soil organic material, this is a special research problem and must necessarily be carried out only on fresh samples. This study can be very useful in increasing our knowledge of the processes of formation and transformation of humus in the soil.

The methodological problems involved are very complicated, and in the absence of data for other soils our conclusions, possibly, do not have general significance. We need to study the effect of drying of soil samples on the composition of the organic material in all soils both for methodological and for general research reasons.

In recent years the attention of investigators has been directed to the study of humus formation chiefly as a biochemical process, and this has been very fruitful. But evidently the direction of this process in different soil groups is greatly affected also by physical conditions — temperature and moisture conditions and their various combinations and seasonal variations. It may be that, for example, the provincial characteristics of the soils within a single soil group, etc., are related to these physical conditions to a considerable extent. Therefore it is important to increase research on the dynamics of the composition of organic material in all soil groups and soil provinces, including the winter season in the program as well as laboratory experiments in which the physical conditions are varied (moisture, temperature, and aeration).

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DETERMINATION OF NITROGEN REQUIREMENTS OF SUGAR CANE BY MAGNITSKIY'S METHOD

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Sugar cane, grown in the Romsovkhozkombinat in the south of Central Asia, responds well to mineral fertilizers. But the fertilizers, which are used on the sugar cane in large quantities ($N_{200}P_{200}K_{120}$) mostly as side dressing, are applied without regard for the actual need of the plant for them, as a rule at a single rate for all plantations.

The methods of plant diagnosis offer a means of rapidly checking the correctness of fertilizer application. In the summer of 1956 we conducted preliminary research on sugar cane plantations during the period of accelerated plant growth at the field laboratory of K. P. Magnitskiy. The research was conducted on the fields of the Romsovkhozkombinat in experiments with fertilizers.

First of all we needed to find a part of the plant in which the sap would respond well to the

conditions of mineral nutrition. The results of the analyses made for this purpose are presented in Table 1.

The supply of nitrogen to the plants was reflected in the nitrate content in the sap of all the plant parts studied, but it was best evidenced in the analysis of the topmost developed internode of a secondary stem, and this was chosen as the means for monitoring the nitrogen nutrition. The choice of the young stem for drop analysis was also favored by the fact that the sap could be removed from it easily and in large quantities, while it took great effort to get even one drop from the leaves because of their appreciable silicification.

Phosphorus and potassium determinations in the same samples did not show such fertilizer-dependent differences in sap composition as for nitrogen. It should be mentioned also that the

Table 1

Content of nitrate nitrogen, phosphorus, and potassium in various parts of the sugar cane plant

Part of plant investigated	Treatment	Results of microchemical analysis		
		N	P	K
		in mg/kg of sap		
Leaf sheath of lower part of main stalk	Without fertilizer	2	20	3400
	NPK	20	10	3100
Blade of same leaves	Without fertilizer	trace	14	—
	NPK	—	—	—
Leaf blade of upper part of main stalk	Without fertilizer	trace	40	—
	NPK	100	40	—
Topmost developed internode of secondary stalk	Without fertilizer	trace	10	2600
	NPK	180	20	2700
Blade of leaves of secondary stalk	Without fertilizer	trace	10	3000
	NPK	70	7	2500

effectiveness of phosphorus and potassium fertilizers on sugar cane was lower than for nitrogen, even though a sugar cane yield of 50 metric tons has been given up to 60 kg of P_2O_5 and 600 kg of K_2O .

Total chemical analysis of the sap of the harvested stalk of sugar cane for nitrogen, phosphorus, and potassium gave the following: N - 0.40%, P_2O_5 - 0.07%, and K_2O - 3.48% of the dry weight of the sap. Thus the total NPK content in the sap of the stalk according to the data of quantitative chemical analysis and the content of the mobile forms of these elements according to the field drop method correlate to a certain extent. According to the data of both methods the concentration of potassium is highest, followed by nitrogen and phosphorus.

After choosing the substance to be analyzed and deciding on the method of analysis, we made determinations in an experiment with different rates of application of nitrogen; the results for

nitrates are presented in Table 2.

A comparison of the data of total chemical analysis, sap analysis by Magnitskiy's method, and the yield show that the microchemical determination of nitrates in the sap of the stalk indicates the supply of nitrogen to sugar cane better than total chemical analysis of the whole plant. Thus we found an almost linear relation between the rate of application of nitrogen in the fertilizer and the concentration of nitrates in the sap of the stalk.

Further work on the problem of plant analysis as applicable to growing sugar cane (the dynamics of the NPK content in the sap, comparison of the methods of different authors [Magnitskiy, Davityan, and others], development of precise methods for taking samples for analysis) will permit its use for control of booster fertilization of sugar cane under production conditions.

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Table 2

Content of nitrogen in sugar cane and yield of useful stalk

Experimental variant	Total chemical analysis					NO ₃ in mg/kg of sap (accel- erated growth)	Yield of useful stalk in metric tons/ha
	N in % of dry weight						
	Accelerated growth			At harvest			
	Whole plant	Green inter- nodes	Leaf	Total shoot	Useful stalk		
Tests on new plowland sown to alfalfa							
Without fertilizer		0.58			0.22	trace	49.7
N ₁₅₀ P ₂₅₀ K ₂₀₀		0.74			0.38	180	68.7
Test on twice-tilled new plowland sown to alfalfa							
Without fertilizer		0.45	0.92	0.62	0.28	12	62.0
P ₂₀₀ K ₁₀₀	0.68	0.43		0.66	0.27	21	64.4
N ₇₅ P ₂₀₀ K ₁₀₀		0.70				46	72.6
N ₁₅₀ P ₂₀₀ K ₁₀₀		0.70				81	81.3
N ₃₀₀ P ₂₀₀ K ₁₀₀	0.76	0.72	1.00	0.98	0.43	170	86.3

CHRONICLE

ACTIVITY OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1958

N. A. RAZORENOVA

In 1958 a great event for Soviet soil scientists occurred — the First Delegates' Congress of Soil Scientists, organized by the All-Union Society of Soil Scientists, was held.

Within the All-Union Society of Soil Scientists (VOP) there are 15 branches in the Soviet Republics, 30 divisions in the large cities of the Russian Socialistic Federated Soviet Republic (RSFSR), and 13 cells in institutions of higher learning, scientific research institutions, and production organizations in the city of Moscow. The total number of members is 2600, and in addition 18 organizations are collective members. A particularly significant growth in membership, both in Moscow and in outlying districts, took place in the period preceding the Congress. The Ukrainian Branch has the largest number of members with 275, and there are 137 in the Leningrad Branch, 103 in the Voronezh Branch, 110 in the Uzbek Branch, and 74 in the Kirghiz Branch.

The work of the Society was conducted by the Organizational Committee. This Committee carried on the work begun in previous years toward the establishment of the permanent commissions, branches, and divisions, and toward the cementing and broadening of international relations. The First Delegates' Congress of Soil Scientists was organized by this Committee. The permanent commissions, branches, and divisions participated actively in the preparation for and work of the Congress.

Scientific papers were presented to the Congress by many soil scientists and specialists in allied fields. A particularly large number of papers came from the branches and divisions.

Much organizational work was conducted in setting up the program, printing materials for the Congress, in the reception of the delegates and foreign guests, and in conducting the tours.

All the preparatory work was done with the participation of members of the VOP — staff members of the V. V. Dokuchayev Soil Institute

of the Academy of Sciences of the USSR, Moscow State University, the Forest Institute of the Academy of Sciences, the Timiryazev Agricultural Academy, and other institutions in Moscow.

Four sessions of the Organizational Committee were devoted to problems of preparing for the Congress. On March 24, 1958, there was a joint session of the All-Union Society of Soil Scientists with the House of Scholars of the Academy of Sciences of the USSR, the V. V. Dokuchayev Soil Institute, and the editors of *Pochvovedeniye*. The session was devoted to a discussion of the work of the journal in 1957 and its tasks for 1958. Academician I. V. Tyurin presented a paper.

The First Delegates' Congress of Soil Scientists took place in Moscow from May 12-17, 1958.¹ The Congress was attended by 242 delegates, more than 700 guests, and 12 foreign scientists. Among the delegates there were representatives of higher institutions of learning, scientific research institutes, and production organizations.

The following papers were read at the plenary sessions (May 12-13): I. V. Tyurin, "Coming and present tasks of Soviet soil scientists"; N. N. Rozov, "The status and development of the classification problem in soil science"; P. A. Letunov, "Soil-geographical zonation"; S. S. Sobolev and M. N. Malyshin, "Quality evaluation (site index) of soils"; A. V. Sokolov, "Soil factors and the effectiveness of fertilizers"; and S. S. Sobolev, "Control of soil erosion in the USSR."

The following sections met from May 14-16: physics, fertility, chemistry, soil genesis and classification, zonation, site index and reclamation of soils, and the subsection on control of soil erosion. The section meetings included 220 papers by members of the VOP and 12

¹ A detailed report on the Congress is given in *Pochvovedeniye* No. 9, 1958.

papers by foreign scientists. The subject matter of these papers was quite diverse, and the nature of the papers gave an insight into the state of the scientific and practical activity of Society members in all branches of soil science.

Twelve scientists from the lands of the Peoples' Democracies participated actively in the Congress of Soil Scientists. They all read papers, and this allowed us to become acquainted with their work and to exchange ideas.

After the Congress ended a coordinating conference was organized at the Soil Institute on problems of soil classification and soil maps of Europe and Asia.

At the plenary session on May 17, a paper was given by the Deputy Chairman of the Organizational Committee of the VOP, Prof. S. V. Zonn, "Activity of the Organizational Committee of the All-Union Society of Soil Scientists." The Congress unanimously approved the activity of the Organizational Committee, and discussed and adopted the Bylaws of the All-Union Society of Soil Scientists.

In closing, the Congress elected a Central Council, a Presidium, and a Revisionary Committee. Fifty members and 6 alternates were elected to the Central Council. Academician I. V. Tyurin was chosen as President. The Congress adopted a detailed resolution, in which it mapped out organizational steps and scientific problems.

A five-day trip was organized after the Congress from Moscow to Kursk to Streletskaya Steppe.

At a meeting of the Bureau of the Division of Biological Sciences of the Academy of Sciences of the USSR on July 1, 1958, a report was presented by Academician I. V. Tyurin, President of the Society, concerning the conduct of the Congress and a resolution was passed confirming the selection of the Central Council, the Presidium, and the Revisionary Committee. The Bylaws adopted by the Congress were approved and recommended to the Presidium of the Academy of Sciences of the USSR for ratification. The Central Council was given the task of publishing the transactions of the Congress. The activity of the Organizational Committee was also approved by the members of the Bureau. The Bylaws of the All-Union Society of Soil Scientists were ratified by the Presidium of the Academy of Sciences of the USSR on August 15, 1958, and at that time the Bylaws were printed in an edition of 3000 copies and distributed to all members.

In order to carry out the decision of the Bureau of the Division of Biological Sciences concerning the publication of the transactions of the Congress, the Chairman of the Committee

directed that the most interesting papers be selected for publication and that the work of each section be reviewed. Arrangements were made with the editors of *Pochvovedeniye* to print these papers in issues of the journal and to make additional reprints of the transactions of the Congress that would later be bound into a collection.

In 1958, *Pochvovedeniye* published the papers from the plenary sessions and 11 of the section papers. The rest will be published in 1959.

In November 1958 the first expanded session of the Central Council was held, and the following resolutions were adopted: a) to hold elections for the governing bodies of the branches and divisions in accordance with Bylaws § 26; b) it approved the management and plans of the permanent commissions; c) it ratified the statutes concerning the Central Revisionary Committee and the Revisionary Committees of the Branches and Divisions; d) approved the program of the Central Council; and 3) approved the permanent glossary committee under the chairmanship of Prof. A. A. Rode.

Under the Central Council there are seven permanent committees headed by distinguished scientists. The first committee, on soil physics, is under the chairmanship of A. A. Rode; Academician I. N. Antipov-Karatayev is chairman of the second, on soil chemistry; Ye. N. Mishustin, corresponding member of the Academy of Sciences of the USSR, is chairman of the third, on soil biology; Academician O. K. Kedrov-Zikhman is chairman of the fourth, on soil fertility; Academician I. V. Tyurin is chairman of the fifth, on soil genesis and classification; Prof. A. N. Rozanov is chairman of the sixth, on soil melioration; and Prof. N. I. Gorbunov is chairman of the seventh, on soil mineralogy. Prof. S. S. Sobolev is chairman of the subsection on control of soil erosion, and Prof. N. Ya. Kats is chairman of the bog soil subsection.

During the first half of 1958 the work of all the committees was devoted to preparations for the First Delegates' Congress. Author groups, consisting of members of the committees, prepared general papers on fundamental problems of soil science. The office of the committees read, edited, and selected 250 papers for the section sessions and supervised the work of the sections at the Congress. In addition, five committees organized and conducted a tour for the delegates to the Congress.

During one year the committees held scientific meetings for presentation of papers and reports; 35 meetings were held. Papers were submitted by workers from the V. V. Dokuchayev Soil Institute of the Academy of Sciences of the USSR, the Timiryazev Agricultural Academy, Moscow State University, the Institute of Water

omy, and other organizations in the city of Moscow and outlying districts. In April the committee on Soil Genesis and Classification held a meeting on the factors and nature of soil formation. Papers were presented by A. A. Zavalishin, V. V. Ponomareva, D. I. Popazov, which evoked lively discussions. At a meeting in May the Soil Chemistry committee heard an expanded version of the Conference paper of the Hungarian scientist Di Gleria on the subject, "Physicochemical and colloidal processes occurring in the soil in the light of the most recent research." In addition, the committees worked on the compilation of the encyclopedic dictionary of soil science (anticipated publication in 1959), and on the editing of the Russian text of the second edition of the bilingual dictionary of the FAO.

The second and fourth committees were concerned with the reading, editing, and translation of papers presented to the conference of committees II and IV of the International Society of Soil Scientists held in August in Hamburg.

The activity of the All-Union Society of Soil Scientists is assuming ever wider scope not only in Moscow but also in the outlying districts. Most of its branches and divisions work is being done in places where there are scientific workers to aid the creativity of its members. The well-rounded programs also promote the increased scientific competence of their members, disseminate soil information, and render scientific assistance to production. At the heads of the branches and divisions there are usually highly qualified specialists in the field of soil science. At the beginning of the year papers were prepared for the First Delegates' Congress of Soil Scientists were given full-scale discussion in the branches and divisions. More than 200 papers from the branches and divisions were included in the program of sectional meetings.

The work of the branches and divisions concentrates basically on the preparation of scientific papers on present problems as applied to local conditions. Thus, in the Ukrainian, Leningrad, Latvian, Lithuanian, and Estonian Branches, and the Voronezh, Bashkir, Kuybyshev, and other divisions, much attention is paid to questions of soil classification, to agricultural zonation of soils, and to the large-scale mapping of the lands of the sovkhoses and kolkhozes. Problems of soil site have received much attention from the Leningrad, Latvian, Lithuanian, and Estonian Branches, and the Gor'kiy and Stalingrad divisions. In the Altay, Omsk, Kazan, and Perm divisions much scientific discussion was devoted to problems of the genesis and reclamation of wetlands and also to problems of fertilizer application and agricultural techniques.

In many branches and divisions official discussion was given to the matters treated at the

meeting of the Joint Committee on Soil Classification, which was held in February 1958 at the V. V. Dokuchayev Soil Institute of the Academy of Sciences of the USSR.

In addition to the presentation of scientific papers the branches and divisions devoted much attention to the dissemination of scientific information on soils, utilizing radio, lectures, and the local press for this purpose. This work was particularly successful during 1958 in the Azerbaijan, North Caucasus, White Russian, Ukrainian, and Latvian Branches, and the Bashkir, Voronezh, Gor'kiy, Dagestan, Tomsk, and other divisions. In the subject matter of the lectures much space was devoted to questions of fertilizer application and the practical use of soil maps in the sovkhoses and kolkhozes.

In the past year contact of branches and divisions with production increased; soil scientists increased their assistance to the producer by consultation, often in the field, by review and discussion of works on soil study at scientific meetings, and by lectures.

In 1958, the agricultural ministries of the Soviet Republics (Azerbaijan, Latvian, Tajik, and Ukrainian) conducted courses for agricultural workers, where members of the All-Union Society of Soil Scientists lectured on soil science and agricultural chemistry.

In the North Caucasus Branch and the Ryzan', Petrozavodsk, and Komi ASSR Divisions, organization of soil-science museums was initiated at agricultural institutes. In the Irkutsk, Komi ASSR, Leningrad, Kiev, Latvian, and Lithuanian Branches and Divisions, trips were organized during the summer for soil scientists where questions of soil classification were resolved directly in the field.

In 1958 the number of regional meetings increased significantly, and members of the VOP in Moscow and outlying districts participated in them. Such meetings, which attracted a wide group of soil scientists, took place in the Kirghiz, Kazakh, Lithuanian, and North Caucasus Branches, and the Voronezh, Bashkir, and Kazan Divisions. At these meetings there were broad discussions of questions of local soil classification, regional division of soils for agricultural purposes, and also the use of soil maps of the sovkhoses and kolkhozes in production.

Many branches and divisions publish their work locally. Thus, the Tomsk Division publishes its work in the *Izvestiya Tomskogo Universiteta*, and the Stalingrad Division in the *Trudy Sel'skokhozyastvennogo Instituta*, while the members of the Leningrad Branch quite often publish in *Pochvovedeniye*.

We should mention the preparation of the

following for publication: Soils of Voronezh Region, by the Voronezh Division; Soil Map of Gor'kiy Region, by the Gor'kiy Division; Volume I of the Transactions of the Lithuanian Branch, by the Lithuanian Branch; and Bulletin of the Kirghiz Branch of the VOP, by the Kirghiz Branch.

With the active participation of the Azerbaijan and Armenian Branches of the VOP, a Soil Science Service was created under the Ministry of Agriculture. The Lithuanian Branch also raised the question of organizing a Soil Science Service in that Republic.

Ye. V. Rubilin (North Caucasus Branch), F. Ya. Gavrilok (Rostov Division), and Ye. S. Blazhniy (Krasnodar Division) published jointly an article in the journal *Sel'skoye Khozyaystvo Severnogo Kavkaza* on the subject "Tasks ahead for the Soil Scientists of the North Caucasus."

In 1958 the international scientific relations of the Society were considerably expanded and strengthened. The President of the Society, I. V. Tyurin, and the Vice-President, B. A. Kovda, corresponding member of the Academy of Sciences of the USSR, who had been elected to the governing body of the Seventh International Soil Congress, took an active part in working out its program. In addition, Committee V, together with soil scientists of many lands, did much work for the International Society of Soil Scientists on the classification of the soils of Europe and Asia.

Soviet scientists participated actively in the conference of Committees II and IV of the International Society of Soil Scientists (ISSS) in Hamburg in the month of August. Members of the ISSS presented 12 papers, including the general paper of Academician I. V. Tyurin and Prof. A. V. Sokolov on the subject "Soil groups and the action of fertilizers." All the papers were included in the program of the conference and published. The conference was attended by a delegation consisting of Academician I. V. Tyurin (Head of the Delegation), Academician

Ya. V. Peive (Latvian Branch), Prof. A. V. Peterburgskiy (Timiryazev Agricultural Academy), and Dr. D. M. Gusseyanova (Azerbaijan Branch).

Members of the ISSS participated in a symposium, organized by UNESCO in Iran, on the problem of control of soil salinization and water in the arid zone. V. A. Kovda presented a general paper on the subject "Fundamentals of the theory and practice of the reclamation and utilization of saline soils in the Arid Zone," and eight papers at the section meetings, including papers of the Azerbaijan Branch (Volobuyev, Agayev), and the Uzbek Branch (Umarov). V. A. Kovda attended the conference as delegate, and the following as tourists: Academician I. N. Antipov-Karatayev, Prof. A. N. Rozanov, and A. A. Kizilova.

Professors A. V. Sokolov, Yu. A. Polyakov, and N. I. Gorbunov attended the Delegates' Conference of Soil Scientists of Poland, and Prof. S. S. Sobolev participated in a congress on the control of soil erosion (Poland).

In June, Academician I. V. Tyurin went to Ghent (Belgium) to attend a meeting on the multilingual dictionary of the FAO, where he presented the Russian text for inclusion in the second edition. I. V. Tyurin also attended a meeting on soil structure in Belgium.

A large group of Soviet scientists, members of the VOP, spent some time in China rendering consultative and practical assistance to specialists in that country: V. A. Kovda, A. N. Rozanov, M. M. Kononova, S. V. Zonn, N. N. Rozov, S. A. Shuvalov, V. A. Nosin, V. V. Yegorov, and others.

In October Academician I. V. Tyurin, Prof. V. A. Frantsesson (All-Union Institute of Fertilizers and Agricultural Soil Science), and Ye. N. Rudneva participated in meetings on problems of soil classification in Rumania and then spent the year in Viet Nam together with Academician I. P. Gerasimov rendering assistance.

WORK OF THE NORTH CAUCASUS BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1958

I. V. RUBILIN

The North Caucasus Branch of the All-Union Society of Soil Scientists began to function in November 1956. The Branch covers three autonomous republics (North Ossetian, Kabardino-Balkarian, and Checheno-Ingush) and Stavropol' subdistrict.

In the short period of its existence the activity of the Branch has been directed primarily toward joining together all those working in the fields of soil science, agronomic chemistry, and related specialties. At present the Branch consists of about 60 members.

Another aspect of the activity of the North Caucasus Branch of the Society since its foundation has been the rendering of assistance to productivity establishments in methods of organizing and conducting soil studies.

The Northern Caucasus has witnessed great developments in soil research and in compiling large-scale maps for the kolkhozes and sovkhozes. This extensive undertaking is being financed by members of the Society — soil scientists of the land-development administrations. The North Caucasus Branch of the VOP is arranging for the pooling of experience in large-scale surveying gained by soil parties of the autonomous republics and subdistricts of the Northern Caucasus by sponsoring interpublic meetings; it is also providing for consultation on methodological problems of large-scale surveying for the benefit of the scientific efforts of institutions of higher learning.

A conference of Society members was held in the city of Ordzhonikidze. The conference was attended by scientific workers and production personnel from Northern Ossetia, Kabardino-Balkaria, Checheno-Ingushetia, and Stavropol' subdistrict. A paper on the subject "Theory of constructing a genetic classification of soils and a plan for the genetic grouping of the soils of the Northern Caucasus" (Ye. V. Rubilin) was heard and discussed at the conference. There were discussions of the reports by soil scientists from the land-development ad-

ministrations of the Checheno-Ingush ASSR (T. N. Protsenko); the Kabardino-Balkarian ASSR (S. N. Duboshina); and Stavropol' subdistrict (V. V. Stotsenko). These reports were devoted to the status of local soil studies.

Scientist members of the Society rendered scientific and methodological assistance to soil scientists and production personnel by means of consultations, especially on problems of soil systematics and classification, as well as by accompanying the soil scientists of land-development parties directly to the places where soil investigations were being conducted.

Consultative assistance was rendered to soil agronomy laboratories on problems of equipment, choice of methods of laboratory analysis, and the technical use of these methods. Thus at the same time the competence of members of the Society engaged in production operations was advanced. Society members also consulted with young soil-science specialists preparing for the candidate's degree, including soil specialists engaged in production activities.

Biology and geography teachers heard lectures on: "Soils and their variations in nature"; "The origin of soils and their geography"; "Soil as a medium for plants"; "The soils of the Northern Caucasus"; "How to organize a tour for students to acquaint them with soils in their natural surroundings"; etc.

Much success was experienced with extensive lectures and talks in the kolkhozes on soils and on ways to improve soil fertility of the area and on use of the large-scale soil map compiled for the kolkhoz. Society members who are soil scientists engaged in production activities, members of soil parties of the land-development administrations, and scientific staff members of institutions of higher learning and experiment stations participated in the project. In 1958, members of the Society gave 110 lectures and provided as many consultations

and talks.

Members of the Society assisted in productivity methods by direct investigation of soils (and other materials) for the kolkhozes, sovkhozes, and other organizations. Thus, for example, K. I. Trofimenko and N. I. Kaloyeva conducted studies, in the field (gorge of the Urukha River) and in the laboratory, on limestones and marls, evaluating the possibility of using them for soil liming.

Assistance was given in organizing the areas of the Ardon vegetable sovkhoz, the kolkhozes of the city of Beslan, Ol'ga village, and others by conducting detailed soil investigations and by making proper recommendations concerning the soils of these farms (Ye. V. Rubilin and M. I. Sikorskaya).

For agricultural purposes this Branch of the Society continued to participate actively in work of the regional division of soils of the autonomous republics of the Northern Caucasus. This regional division will serve as a scientific basis for the correct allocation of agricultural production and more rational land utilization. This work is being finished for the North Ossetian ASSR (Ye. V. Rubilin and K. I. Trofimenko) and is being organized for the Kabardino-Balkarian ASSR and the Checheno-Ingush ASSR. An inter-republic meeting on this subject is planned for the beginning of 1959.

The North Caucasus Branch of the VOP is arranging for the development of methodological bases for the site classification of soils of the Northern Caucasus and for the construction of a site-quality index scale. This work is being done by local soil scientists together with specialists on the economics of agriculture.

Society members are conducting studies on the problem of the genesis and classification of forest soils and chernozems of the foothills of northern slopes of the Central Caucasus, and on chestnut soils of the Eastern Ciscaucasus.

Many Society Members are engaged in developing effective methods of treating soils to improve their fertility. Studies are continuing on the composition of the organic fraction of the most important soil groups of the Northern Caucasus. Extensive investigations on hydrochemical problems are being carried out by Society members in the Northern Caucasus.

In order to strengthen popular awareness of soil science and to mobilize agriculture workers for the solution of pressing problems in soil science, three authors (F. Ya. Gavrilyn, Ye. S. Blazhniy, and Ye. V. Rubilin) prepared an article for the journal Agriculture of the Northern Caucasus on the problems facing soil scientists in the Northern Caucasus. The article was written in accordance with the paper of the President of the VOP, Academician I. V. Tyurin, and the resolutions of the First Delegates' Congress of Soil Scientists of the USSR.

In order to disseminate soil information among the people, members of the VOP in the Northern Caucasus set up a section on soils in the North Ossetian Museum of Regional Studies supplementing the existing soils museum at the North Ossetian Agricultural Institute. Cooperation will be given in organizing a soil museum at Kabardino-Balkarian University and the Soil Science Section at the Checheno-Ingush Museum of Regional Studies in the city of Grozny.

INFORMATION ON PREPARATIONS FOR THE SEVENTH INTERNATIONAL CONGRESS OF SOIL SCIENTISTS IN 1960, MADISON, WISCONSIN, USA

The Central Council of the All-Union Society of Soil Scientists has received the following information from the Committee for the Preparation of the Program of the Seventh International Congress of Soil Scientists:

I. Organizational Questions:

a) 400 papers will be presented; these will be published following the Congress.

b) Prior to the Congress working papers will be reproduced to the extent of two pages (2-28 cm).

c) In addition to the official opening and closing sessions, three general sessions are planned for the Congress, with papers from the Committees and 40 half-day sessions of the Committees.

II. Calendar Adopted for Preparations for Congress:

October 1, 1958. First report.

December 1, 1958. Report on work of the Committees (approval of general speakers and consideration of papers).

January 1, 1959. Second report in the form of a Bulletin of the ISSS.

April 1, 1959. Third report.

January 1, 1959. Final data for accepting bids for papers.

October 1, 1959. Fourth report.

January 1, 1960. Final data for accepting working papers and applications for tours.

May 1, 1960. Final data for making pre-Congress payment (not returnable). Papers of persons who have not paid the fee will be eliminated from the program of the Congress.

July 1, 1960. Final date for submitting complete text of papers; those submitted late will not be published.

III. Preliminary Program of the Congress:

August 15, 1960 (Monday). Opening of the Congress in Madison, Wisconsin. General session (three papers).

August 16 and 17. Committee sessions (specialized papers).

August 18. Morning: field trip; afternoon: General session (2 papers).

August 19. Morning: Committee sessions; afternoon: General session (2 papers).

August 20. Committee sessions (specialized papers).

August 21. Sunday: free day.

August 22. Committee sessions; afternoon: closing of the Congress.

Presidium of the Council of the All-Union Society of Soil Scientists

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